

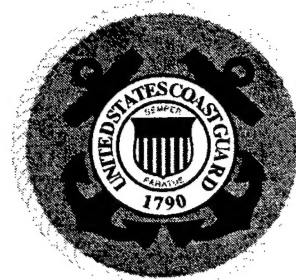
U.S. Coast Guard Research and Development Center
1082 Shennecossett Road, Groton, CT 06340-6096

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**Development of an Endurance Management Plan
for U.S. Coast Guard Air Stations – Phase I**



Final Report
August 1998



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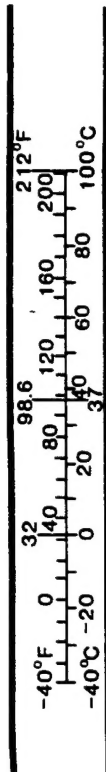


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16. Abstract (200 words or less) <p>United States Coast Guard flight crews were evaluated to assess the impact of unit operational tempo on crew endurance and alertness. This study was conducted at Air Stations Miami and Cape May. The evaluation of sleep and activity patterns indicated that aircrews at Air Station Miami experienced dramatic variability in their individual sleep/wake cycle, with changes in rise time varying more than three hours several times within a month or a week. This resulted in crews at Air Station Miami having significantly larger differences in the time of day of daylight exposure than found at Air Station Cape May. Daily changes in daylight exposure time associated with changes in daily rise times are likely to induce lack of stability of the sleep/wake cycle and in the internal synchronization of the biological clock. The process of adapting to changes in daylight exposure is associated with the disruption of the sleep/wake cycle, fatigue elevation, deterioration of performance, and discomfort associated with gastrointestinal disorders. Recommendations for managing crew endurance include: 1) minimizing the calling to duty of personnel who are otherwise off-duty, 2) improving the sleep environment at the air station to minimize unnecessary disruptions and noise, and 3) implementing an educational program to disseminate sleep hygiene and endurance practices information throughout all rank and occupational levels.</p>					
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures				Approximate Conversions from Metric Measures			
Symbol	When You Know	Multiply By	To Find	Symbol	When You Know	Multiply By	To Find
LENGTH				LENGTH			
in	inches	* 2.5	centimeters	mm	millimeters	0.04	inches
ft	feet	30	centimeters	cm	centimeters	0.4	inches
yd	yards	0.9	meters	m	meters	3.3	feet
mi	miles	1.6	kilometers	km	kilometers	1.1	yards
						0.6	miles
AREA				AREA			
in ²	square inches	6.5	square centimeters	cm ²	square centimeters	0.16	square inches
ft ²	square feet	0.09	square meters	m ²	square meters	1.2	square yards
yd ²	square yards	0.8	square meters	km ²	square kilometers	0.4	square miles
mi ²	square miles	2.6	square kilometers	ha	hectares (10,000 m ²)	2.5	acres
	acres	0.4	hectares				
MASS (WEIGHT)				MASS (WEIGHT)			
oz	ounces	28	grams	g	grams	0.035	ounces
lb	pounds	0.45	kilograms	kg	kilograms	2.2	pounds
	short tons (2000 lb)	0.9	tonnes	t	tonnes (1000 kg)	1.1	short tons
VOLUME				VOLUME			
tsp	teaspoons	5	milliliters	ml	milliliters	0.03	fluid ounces
tbsp	tablespoons	15	milliliters	l	liters	0.125	cups
fl oz	fluid ounces	30	milliliters	l	liters	2.1	pints
c	cups	0.24	liters	l	liters	1.06	quarts
pt	pints	0.47	liters	l	liters	0.26	gallons
qt	quarts	0.95	liters	m ³	cubic meters	35	cubic feet
gal	gallons	3.8	liters	m ³	cubic meters	1.3	cubic yards
ft ³	cubic feet	0.03	cubic meters				
yd ³	cubic yards	0.76	cubic meters				
TEMPERATURE (EXACT)				TEMPERATURE (EXACT)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature

* 1 in = 2.54 (exactly).



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We thank Mr. Charles Ferry of the U.S. Army Aeromedical Research Laboratory, and Mrs. Crystal Cruz at Civil Aeromedical Institute for their contributions to data collection and analysis. Thanks also goes to Dr. Anita Rothblum of U.S. Coast Guard Research and Development Center and Ms. Vonnie Summers for their editorial comments, and to Mrs. Bettie Proctor for her persistent effort to improve the quality of this report.

EXECUTIVE SUMMARY

Problem

An analysis of civilian and military aviation mishaps suggests that human factors are the primary cause of over 60% of the events and the secondary contributors in virtually all mishaps. More specifically, contributing causes of mishaps are long duty hours, rotating work schedules, staffing levels, operational tempo, and crew fatigue. These factors are part of aviation operational environments in varying degrees and their synergistic effect can degrade performance, reduce safety, and increase the probability of loss of life and damage to equipment. A real world concern exists in the Coast Guard aviation community because these aversive conditions can be part of many mission scenarios.

Approach

In 1996, the United States Coast Guard Research and Development Center (USCG R&DC) coordinated a multi-agency¹ research effort to answer the safety concerns in the U.S. Coast Guard aviation community. The primary purpose of the research was to evaluate the impact of Coast Guard operations on aviation personnel's endurance during high tempo operations. A secondary objective of this research project was to design endurance plans specific to Coast Guard operations to prevent performance degradation in Air Stations at-large.

Background

This project was conducted in the summer months during normal operations at Air Station Cape May (1996) and Air Station Miami (1997). The research plan consisted of three (3) separate evaluations:

- 1) A crew endurance evaluation consisting of daily sleep, work/rest cycles, and workload data using wrist sleep monitors, logbooks, and questionnaires;
- 2) An alertness evaluation using a test of sleep latencies and a maintenance of wakefulness test (MWT); and
- 3) A cognitive performance evaluation using a Psychomotor Vigilance Task (PVT) and a Multi-Task Assessment Battery.

The results of the cognitive evaluation will be presented in a separate report under the auspices of the Civil Aeromedical Institute (CAMI).

Conclusions and Recommendations

In the evaluations conducted at Air Stations Cape May and Miami, alertness and endurance data indicate that Miami aircrews were more apt to experience drastic changes in their sleep/wake cycles and daylight exposure times. Changes in rise times and daylight exposure times varied

¹ U.S. Coast Guard Research and Development Center, Civil Aeromedical Institute, and the U.S. Army

often by more than three hours and these variations occurred several times within a month or sometimes within a week. These changes in daylight exposure times were likely to induce lack of stability of the sleep/wake cycle and of the internal timing of the biological clock. The results of sleep and wakefulness tests supported this notion, and provided evidence of reduced alertness. Latencies to sleep onset in both sleep and wakefulness tests indicated a pattern of alertness degradation similar to the deterioration experienced by patients suffering from sleep disorders.

Recommendation: Make Work Schedules Predictable

Work schedules are a target for potential improvements. One unique characteristic of the work scheduling system used at Air Station Miami was its flexibility. This characteristic allowed calling back to duty personnel who were otherwise off-duty to fill in for crewmembers that requested unscheduled time off. This practice can result in frequent disruptions of personal and family time. These effects can be minimized if personnel are called back to duty only when required by increased operational tempo or by unavoidable health impairments. This recommendation restricts the current flexibility of work schedules, but its benefits extend from a more reliable and predictable work schedule to a significant increase in family and personal quality time. From a human endurance point of view, the quality of time-off may be as important as the quality and duration of sleep.

Recommendation: Improve Sleeping Environments

Improvements to the sleep environment may also contribute to ensuring that personnel at Miami Air Station experience uninterrupted sleep during 24-hour duty days. During the evaluation of environmental conditions, doors in the hallways of sleeping quarters produced loud sounds upon closing. Suggestions to equip the doorframes with thick foam weather stripping that may soften the slamming sound were met with favorable responses. In addition, we recommend minimizing the use of "piped calls" to avoid disruption in enlisted and officer quarters. Selectively disabling speakers and installing direct telephone lines with access to flight operations may be a practical and feasible approach.

Recommendation: Educate CG Personnel on Endurance Management

We recommend the aggressive use of an educational program to disseminate sleep hygiene and endurance practices information throughout all ranks and occupational levels. This action is particularly relevant to occupational environments with high operational tempo. In these situations, as is the case at Air Station Miami, personal choices may be extremely important in the maintenance of endurance. For instance, individuals can make choices to nap when the opportunity arises, or to choose to delay completing paperwork associated with collateral duties in favor of a needed nap prior to a night mission. Safety down days or scheduled workshops can provide the environment to disseminate information on personal endurance plans. Educational materials are available at the USCG Research and Development Center in Groton, CT.

Recommendation: Implement the Endurance Plan at Air Station Miami

Air Station Miami recently sponsored a crew endurance seminar conducted by USCG R&D and U.S. Coast Guard Headquarters (HQ) staff. This is one of the many actions that the Air Station's command staff has supported after this initial evaluation. Other significant changes to date constitute the formation of a quality action team (QAT) to determine possible changes in work-schedule practices, improvements to the sleep environment, and the organization of an educational program. Once the QAT designs and implements changes to improve performance and prevent stress and sleepiness in the operational environment, a second evaluation will determine the efficacy of the endurance plan. Coast Guard Research and Development resources have been assigned to assist Air Station Miami to evaluate the efficacy of the endurance plan.

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1 Introduction

1.1 Background

An analysis of civilian and military aviation mishaps suggests that human factors are the primary cause of over 60% of the events and secondary contributors in virtually all mishaps. More specifically, identifiable causes of mishaps are long duty hours, specific relief times, staffing levels, operational tempo, and crew fatigue. These factors are part of aviation operational environments in varying degrees and their synergistic effect can degrade performance, reduce safety, and increase the probability of loss of life and damage to equipment. A real world concern exists in the Coast Guard aviation community because these aversive conditions can be part of many mission scenarios.

Coast Guard operational objectives require that aviation facilities maintain a 24-hour capability. Air Stations adopt rotating shift work schedules and 24-hour duty days to meet these requirements. During periods of persistent high operational tempo, these duty schedules can induce chronic sleep debt, disrupted sleep, disruption of family and social life, and lack of sufficient time off. The synergistic effect of these conditions can increase stress, deplete physical energy and mental ability, degrade performance, and increase the risk level during missions. High operational tempo can result in the need to schedule personnel to work more than five days per week and to reduce the numbers of days off per week. If this condition becomes chronic, personnel may have trouble balancing family and social life with work related demands. The resulting stress of lacking time to dedicate to family members and friends can result in significant levels of stress and distraction during duty hours.

Two other major contributors to the deterioration of performance and alertness are the accumulation of sleep loss and the disruption of the regulation of energy resources. Rotating duty cycles, and on-call 24-hour duty days, can result in reductions of time available for sleep and induction of drastic daily variations in bedtimes and rise times. As a society, we are aware of the impact of sleep loss on performance, but we are much less aware of the effects that drastic variations in sleep and rise times exert on daily availability of mental and energy resources.

During daytime duty hours, the body's biological clock system regulates rise and sleep onset times using the time of daylight exposure to set its internal timing. This system is a biological mechanism that synchronizes daily physiological and cognitive rhythms, thus regulating the availability of resources throughout the day. Exposure to daylight of approximately 1000 lux in intensity (similar to the brightness seen at dawn) or greater, after awakening from daily nighttime sleep, sets the biological clock via the stimulation of light sensitive tissue (e.g., retina of the eye). Light sensitive tissue conveys a neural message to specific areas of the brain (e.g., deep brain nuclei) and to glands (e.g., pituitary, pineal) which constitute the human biological timing system. Consistent daylight exposure from day to day maintains the biological clock's timing and it ensures that mental resources and physical energy will be regularly available throughout the day. However, experiencing daily and frequent changes in the time of day of daylight exposure disrupts biological timing and results in the induction of sleepiness, performance degradation, insomnia, gastrointestinal disorders, and overall malaise. These symptoms are

similar to those experienced by travelers who cross several time zones in a single day (Jet-Lag). When the disruption of the biological clock is induced by varying duty schedules and not by travel across time zones, the resulting condition is referred to as Shift-Lag (Kogi, 1985).

Enduring the adverse impact of reduced energy, impaired mental ability, and emotional drain on performance, deliberate efforts are required to offset these effects. Crew endurance plans designed to ensure the availability of cognitive and physical resources during duty hours are necessary to prevent performance degradation. Efficient crew endurance plans prescribe practical methods to coordinate mission driven duty cycles with crew rest schedules, to maintain a balance between family life and work demands, and to prevent the disruption of the body's biological clock. Thus, in 1996, the U.S. Coast Guard Research and Development Center (USCG R&DC) in Groton, CT, coordinated a multi-agency (USCG, Civil Aeromedical Institute, and U.S. Army) research effort to answer the safety concerns in the USCG aviation community. The primary purpose of the research was to evaluate the impact of Coast Guard operational policies on aviation personnel's endurance ability during high tempo operations. A secondary objective of this research project was to design endurance plans specific to CG operations to prevent performance degradation at Air Stations at-large.

A Crew Endurance Management System (CEMS) designed to prevent performance degradation in Army aviation missions was used to develop a plan to prevent sleep debt, to optimize crew rest, and to ensure safety in USCG aviation missions (Comperatore, 1996). The CEMS approach has been used effectively in Army aviation operations to coordinate mission specific objectives, crew rest, workload, personnel strength, work schedules, administrative duties, and equipment constraints during aviation missions (Comperatore, Lieberman, Crowley, Kirby, and Adams, 1996). The CEMS approach used in this project consists of three phases:

- 1) Assessment of the impact of unit operational tempo on personnel endurance and alertness;
- 2) Development, implementation, and re-evaluation of a plan to prevent the insidious effects of long duty days (more than eight hours per day), sustained work days (infrequent days off), and sleep loss on performance; and
- 3) Implementation of an educational program to provide information on personal coping strategies and optimal unit crew rest plans.

This report addresses results pertinent to the Phase I evaluation conducted at Air Stations Cape May and Miami in 1996 and 1997, respectively. This evaluation included the study of the effects of work/rest schedules, watch standing schedules, deployment to cutters, and high tempo operations on crew rest, safety, well being, and performance.

2 Methods

2.1 General Approach

This project was conducted in the summer months during normal operations at Air Station Cape May (1996) and Air Station Miami (1997). The research plan consisted of three separate evaluations:

- 1) A crew endurance evaluation consisting of daily sleep, work/rest cycles, and workload using wrist activity monitors, logbooks, and questionnaires;
- 2) An alertness evaluation using a test of sleep latencies and a maintenance of wakefulness test (MWT); and
- 3) A cognitive performance evaluation using the Psychomotor Vigilance Task (PVT) and the Multi-Task Assessment Battery.

Questionnaires, interviews, wrist activity monitors (WAMs), logbooks, cognitive performance, electroencephalography (EEG), and environmental observations were used to document alertness levels, environmental stresses, and workload throughout 30 days at each Air Station. The examination of operational policies and procedures used at each Air Station provided information on the organizational factors influencing operations. Environmental observations were used to determine factors known to interfere with sleep (e.g., ambient noise).

In the following sections of this report, the results will include data depicting the outcome of the crew endurance and alertness evaluations. However, the results of the cognitive evaluation will be presented in a separate report under the auspices of the Civil Aeromedical Institute.

2.2 Participants

Aircrew from Air Station Cape May (19 males) and Air Station Miami (42 males) volunteered to participate in the study. All volunteers were in good physical condition, with no history of abnormal EEG, seizures, or pre-existing health problems, and each maintained a current medical file with the Air Stations' medical staff. Volunteers were briefed on the right to withdraw from the evaluation without consequences, confidentiality of the data, experimental procedures, and benefits and risks associated with participating in the study. After the research staff answered all questions and concerns, volunteers were asked to sign an informed consent form prior to their participation. All participants received an identification number used on all measures (i.e., logbooks, questionnaires, performance data files, etc.) to identify their data throughout the study. Risks to participants were minimal because the research plan did not require significant changes in their daily duty routines, or prescribe the use of any invasive techniques. The experimental procedures used to evaluate crew endurance were reviewed and approved by the Civil Aeromedical Institute's (CAMI) Research Review Board resident at the Civil Aeromedical Institute in Oklahoma City, OK.

2.3 Procedure

2.3.1 Crew Endurance Evaluation

The evaluation of endurance consisted of documenting the impact of operational tempo and duty schedules on personnel's ability to restore alertness and energy resources. For this purpose, volunteer unit members wore wrist activity and light monitors throughout the study to document daily a) sleep duration, b) rise times, c) bedtimes, and d) time of day and duration of daylight exposure. Sleep duration and rise times constituted individual sleep histories depicting the impact of duty schedules and operational tempo on personnel's ability to obtain sufficient rest from day to day. These data provided indications of how well crewmembers used off duty periods to rest and to recuperate after 24-hour duty days, nighttime operations, and routine duty days. Following the pattern and timing of daily exposure to daylight provided information on how well crewmembers adapted their internal biological clock (controlling daily cognitive and physical energy cycles) to the work schedules. Irregular patterns of daylight exposures (e.g., frequent variations in clock times exceeding two hours) can result in sleepiness, overall feelings of malaise, and performance degradation (as in jet-lag, but induced by long duty days and varying work schedules).

2.3.1.1 Wrist Activity Monitors (WAMs)

A Wrist Activity Monitor (WAM) is a wrist-worn unit (about the size of a large wristwatch) containing a battery-powered microprocessor, a motion sensor, and a real-time clock. The sensor unit detects movement inducing even very low level accelerations (e.g., from 0.5 to 3.2 Gz). During the study at both Air Stations, motion was recorded 24 hours per day for approximately 30 days. Twenty-four hour profiles of low and high level activity allowed the determination of sleep onset and duration. Daily sleep duration, derived from the activity profile, depicted the amount of sleep that personnel were able to obtain throughout the study period. This technique provided specific and objective information on the impact of work schedules on daily sleep.

2.3.1.2 Light Exposure Timing

Wrist activity monitors featured a silicon photocell that when exposed to environmental lighting was capable of measuring the time of day of daylight exposure, duration of the exposure period, and the illumination level. Following the pattern and timing of daily exposure to daylight provided information on how well crewmembers adapted their internal biological clock (controlling daily sleep and energy cycles) to the work schedules. Irregular patterns of daylight exposures (e.g., frequent variations in clock times exceeding two hours) can result in sleepiness, feelings of malaise, and performance degradation (as in jet-lag, but induced by work schedules).

2.3.1.3 Subjective Information

Logbooks and questionnaires (e.g., sleep disorders) were administered to document participants' health status and daily activities such as regular duty hours, breaks, and on-call duty hours.

2.3.2 Alertness Evaluation

This evaluation documented personnel's ability to maintain alertness at times of the day when cognitive and physical energy would be available at peak levels (daylight hours). In clinical settings, sleep latency tests are used regularly to determine whether patients experiencing sleep disorders suffer from severe daytime sleepiness that may compromise safety. These tests involve monitoring brain activity while patients attempt to sleep (Sleep Latency Test or SLT) or to maintain wakefulness (Maintenance of Wakefulness Test or MWT). During these tests, noticeable changes in brain activity indicate the exact moment of sleep onset. The number of minutes that lapse from the beginning of the test to the time of sleep onset is the sleep latency. Under normal conditions, sleep latencies for either the SLT or the MWT exceed ten minutes. In cases involving sleep disorders that drastically disrupt sleep, latencies fall below ten minutes. Latencies below six minutes indicate severe alertness degradation. Thus, the procedures in the alertness evaluation for this study borrow heavily from the clinical procedures used in the SLTs and MWTs.

2.3.2.1 Sleep and Wakefulness Tests

Each alertness evaluation session consisted of two tests designed to measure the time taken by participants to fall asleep under instructions to sleep (the sleep latency test) and under instructions to stay awake (the wakefulness test). Fifteen participants at the Air Station Miami volunteered to undergo sleep and wakefulness test sessions before deploying to serve at remote locations, during the deployment, and upon return to Air Station Miami. On the day of the test, participants reported to the testing location every three hours throughout the day. Deployment schedules were particularly variable as mission assignments were announced sometimes with less than one-two weeks notice. Flight and collateral duties contributed to the disruption of sleep latency test schedules. Consequently, participation in these tests varied considerably in terms of the number of volunteers in each of the three conditions (pre-deployment, deployed, and post-deployment). Eight volunteers were tested pre-deployment, six during deployment, and thirteen post-deployment. In the pre-deployment condition, participants were tested approximately one-two weeks before departure. During the deployment, a research team traveled to pre-determined port locations (Cuba and Puerto Rico) during the patrol and tested volunteers immediately upon arrival at the port. In the post-deployment condition, participants were tested one-two days after arrival at the Air Station.

In both tests, volunteers rested on a comfortable bed with eyes closed and lights off in a room equipped with environmental temperature control (temperature maintained between 65-75° F). During both tests, brain activity was monitored to detect the transition from wakefulness to sleep using clinical methodology employed routinely in sleep laboratories (Rechtschaffen and Kales,

1968). In the first test, participants were instructed to allow themselves to fall asleep and they were awakened after two continuous minutes of sleep. A break of five minutes, under lights on, was used to separate the first test from the second test. At the end of the break, the lights were turned off and participants were asked to relax, but to try to remain awake (wakefulness test). Participants were allowed to sleep for two minutes and then awakened.

3 Results

Since it was not possible to control watch schedules, workload, and work schedules during an actual patrol, we favored the use of descriptive statistics to the use of statistical analyses requiring (a-priori) hypothesis testing. We used statistical tests involving Analysis of Variance (ANOVA) or contrast analysis (Tukey's Honest Significant Difference Tests, HSD) to supplement descriptive statistics. However, we would like to stress that these techniques were not intended to reflect the implementation of hypothesis testing statistical designs.

Generalizations from this study are limited to the environmental conditions, operational tempo, and duty schedules experienced by the participants. As is the case in many field studies, our objective was limited to the documentation of changes in alertness and endurance under real-world conditions and to the identification of work related conditions influencing these changes.

3.1 Endurance Evaluation

3.1.1 Sleep and Activity Histories

Activity and light exposure data plotted as a function of time of day created records of high and low activity throughout 24-hour days. Days stacked sequentially produced a day by day history of sleep and activity for each participant. Please refer to Appendix A, subject 03. The vertical bars indicate frequency of activity counts and their presence denotes wakefulness. Their absence or substantial reduction indicates sleep (see Appendix A, subject 03, from 2300-0600). Clock times presented at the top of the illustration indicate the passage of time from left to right. Dates indicate changes from day to day along the left and right sides of the illustration. A legend box, located in the upper right hand corner, indicates the dynamic range of activity counts. High frequency counts forming rectangular or square shapes (e.g., subject 03, on June 19, from 1800-2000) represent periods of high activity levels and are generally associated with exercise (e.g., participation in soccer game, weight lifting, running, walking, etc.). Also illustrated in the sleep and activity histories are the onset and duration of light exposure. Dots placed above activity bars indicate exposure to light of at least 1,000 lux in intensity. The number 8,000, shown on the right side, indicate the mid-level of the dynamic range displayed on these illustrations. Levels of 1,000 lux or above have been shown to consistently regulate the timing of the body's biological clock.

The patterns of sleep, activity, and light exposure were analyzed for the purpose to detect abrupt shifts in sleep onset times, rise times, and biological clock synchronization. Frequent and abrupt changes in these parameters mediate sleep disruption, and are associated with work schedules or personal habits that are detrimental to physical and mental endurance.

3.1.2 Sleep and Activity Histories at Air Station Cape May

Cape May personnel exhibited a consistent pattern of sleep and activity with few perturbations. Bedtimes and rise times were relatively consistent except for periods associated with 24-hour duty days. Please refer to Appendix A, subjects 03, 07, 10, and 17. These examples are representative of the Air Station Cape May data set. In these examples, the decrease in activity denoting bedtime occurs consistently from 2000-0000 and rise times (sustained increase of activity in the early morning hours) occur at similar times from day to day throughout each record. Scanning downward through each illustration, the beginning of morning daylight exposure can be seen to occur consistently in association with rise times.

Exceptions to this pattern are present in some instances. For example, refer to subject 10 (Appendix A) and scan downward from the beginning of the page to the data on 21 June and 25 June. On 21 June, sleep onset did not begin until 0100. Low activity was present between 2000-2245, but it was not sleep. This extension of the duty day was associated with a 24-hour duty day. Likewise on 25 June, activity was present throughout the night that could be traced to duty related activities.

Similarly, the record of subject 17 (Appendix A) provides a more extensive example (18 consecutive days) of the few instances in which duty hours resulted in the disruption of sleep at Air Station Cape May. Refer to 25 June and follow the activity period from left to right. Note that sleep is fragmented and it occurs from 2000-2200, from 2330-0245, from 0315-0445, and from 0530-0715. These disruptions were duty related. However, continuing the scan from day to day (see both subject 17 and subject 17 continuation illustration beginning on 2 July) reveals a consistent pattern of bedtimes, rise times, and sleep duration.

3.1.3 Sleep and Activity Histories at Air Station Miami

In contrast to the stable patterns of sleep and activity from Air Station Cape May, personnel at Air Station Miami exhibited a variety of individual patterns in response to high tempo operations and varying duty cycles. Throughout the following discussion, please refer to the sleep and activity histories in Appendix B. In general, activity and sleep histories revealed a pattern of varying bedtimes and rise times occurring frequently in individual records. The records in Appendix B (for subjects 24, 35, 68, 236, 286, 287) illustrate the variety of responses resulting from the work schedule experienced by Air Station Miami crewmembers, maintenance personnel, and staff officers. These examples are representative of the Air Station Miami data set. For instance, notice in subject 24 that throughout a period of seven days, bedtimes and rise times are rarely similar from day to day (except for 20-21 June). On 16 June, participant 24 woke-up before 0600 and worked during the night on 17-18 June. His sleep was fragmented into two periods, from 1530-1815 and from 0400-0800. Although he had two days to recover lost sleep his work periods extended until 0400 from 21-22 June. Abruptly, on 23 June, he rose before 0600 and reported for work at approximately 0700 as on 16 June. This pattern of sleep and activity resulted in varying light exposure times from 16-23 June and contributed to the disruption of the internal timing of his biological clock. This effect was particularly damaging on

days in which he saw daylight earlier than on the previous day. In those instances (19 June, 22-23 June), the biological clock received inputs that advanced the peak availability of resources to earlier times of the day, but that also induced a reduction of these resources earlier in the evening. Changing daylight exposure times, after nighttime sleep, to earlier times from day to day induces systematic advances in the timing of the biological clock. Rapid changes in light inputs to the clock disrupt its internal timing and these changes can induce symptoms similar to those experienced in the case of jet-lag (e.g., fatigue, insomnia, gastrointestinal disorders, depression, etc.).

In the sleep history for subject 35 (Appendix B), work periods are indicated between two opposing open arrows (see 17-18 June*). Open and starred circles indicate the beginning and end of flights, see 21-22 June. Thus, in this illustration, it is possible to examine activity, sleep, light exposure, duty cycles, and flight times. This example illustrates that although sleep duration may not vary, disruption of the timing of the biological clock can result in sleepiness in the absence of sleep loss. Note that work and rest periods induce advancing light inputs to the biological clock on 21 June, 23 June, and 25 June. In most cases, the duration of sleep ranges from six to nine hours. This pattern is certainly less damaging to sleep and performance than that of subject 24. However, note that some flights do occur in association with days in which this pilot (35) was required to advance his rise time at or about 0600 (see June 23 and 25).

The impact of an advance is the experience of reduced alertness during the hours that the brain expects to be sleeping. Refer to 21-22 June and scan down to 23 June at 0605. Note that the flight time is between 0800-1000. Thus, this crewmember is likely to have experienced reduced alertness during the flight since he was asleep at that hour on 22 June. A similar pattern repeated between 23-25 June. This profile of sleep and activity is similar to the experience of changing to daylight savings time in the spring, with the exception that in this case the process repeats itself throughout a four to five day period.

Subject 236 (Appendix B) depicts another pattern of advancing inputs to the biological clock resulting in the induction of sleep loss and in the disruption of the timing of the biological clock. Please scan from 26-29 June and note that there is an advance in rise times of approximately four hours that begins on 30 June and persists until July 4. This abrupt change in rise times and daylight exposure times resulted in a reduction of sleep duration (compare sleep from 28-29 June with sleep from 29-30 June) that did not recover until 3-4 July. On this date, this participant returned to his preferred bedtime and rise time. This pattern of sleep and activity can result in sleepiness during duty hours, particularly during the morning hours, induced by the synergistic effects of disruption of biological clock timing and loss of sleep time.

Finally, subject 286 also illustrates the synergism of sleep deprivation and disruption of the biological clock's timing. However, this case also suggests that for this volunteer, as it may be the case in many instances at Air Station Miami, sleep loss and biological clock disruption were a chronic experience from 23 June through 9 July.

* Subject was not given a WAM until 0900, which accounts for the lack of activity data in the beginning of this work period.

This analysis of sleep and activity histories indicated that personnel at Air Station Miami experienced adverse consequences of high operational tempo and variable work schedules in the form of advances in rise times, sleepiness, and disruption of biological timing. The following sections provide quantitative evidence supporting this notion.

3.2 Estimation of Daily Inputs to the Body Clock

Calculations of daily rise and light exposure times numerically depicted the consistency of the sleep/wake cycle and of light signals to the biological clock. Individual frequency histograms of first daylight exposure time (after normal sleep) were used to discern the pattern of inputs to the biological clock's timing system. Frequency histograms depict the percent of days observed under differences in daylight exposure times from day to day. These difference scores were grouped in categories beginning with zero hour and increasing by one hour intervals (e.g., zero-one hour, one to two hours, etc.). A one-way analysis of variance (ANOVA), using the between-subjects factor air station (Miami vs Cape May), was applied to the difference scores data to ascertain whether the two groups of volunteers significantly differed in their management of biological timing.

Frequently observed large differences in light exposure times (above three hours) provided evidence of unstable inputs to the biological clock. This pattern of inputs was unstable because it resulted in daily delays or advances in the biological clock's internal timing. These unstable inputs induced shifts in performance and physiological rhythms under the regulatory control of the biological clock. Frequent shifting in these rhythms can result in changes in the time of day in which physiological (e.g., physical stamina and alertness) and cognitive resources (e.g., mental ability to make decisions) are available. In brief, sleepiness may occur at times when least expected, perhaps during a mission flight.

Similar to the approach used with daylight exposure differences, the calculation of daily differences in rise times between successive days provided evidence of stable or unstable individual sleep/wake cycles. Frequently observed, large daily rise time differences indicated unstable sleep schedules resulting in reductions of sleep duration (Comperatore and Allan, 1997).

Part of this evaluation was individual interviews, administration of questionnaires, and inspections of sleeping quarters at both air stations. These data characterized work schedules and environmental conditions experienced by members of both groups.

3.2.1 Daily Differences in Daylight Exposure Times

Personnel in both Miami and Cape May exhibited the largest percent of days under the zero to one hour (40% and 45%, respectively) and one to two hour daily differences categories (20% and 25%, respectively). Figure 1 depicts these differences in light exposure times up to two hours. Cape May personnel exhibited a greater percentage of days under the zero to two hour categories than Miami Air Station personnel did. Forty percent of all daily difference scores for the Miami Air Station exceeded \pm two hours, while, for the Cape May Station only 30% of daily difference

scores exceeded \pm two hours. Figure 2 depicts these differences. Note that Cape May personnel exhibited a greater frequency of days with daylight exposure time changes below two hours. Beyond two hours the pattern reverses to reveal that Miami personnel exhibited a greater frequency of changes in the two hours of daily difference scores (see Figure 2). Statistical analysis applied to the differences in time of day of daylight exposure supported the notion that Miami personnel changed daylight exposure by more than two hours more frequently than Cape May personnel².

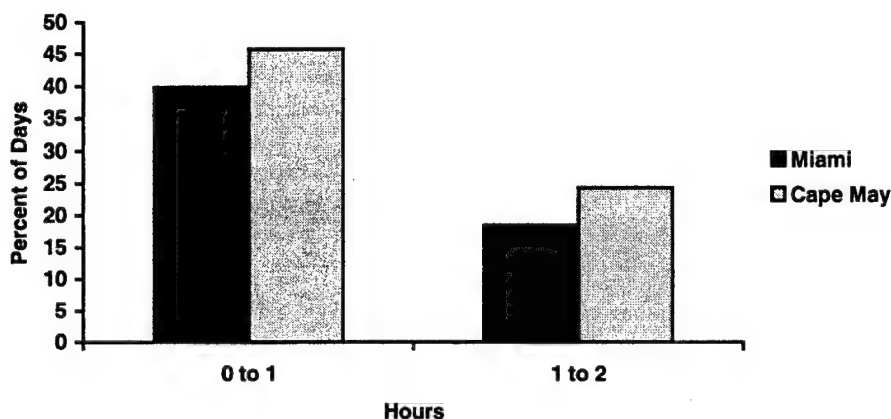


Figure 1. Percent of Days Participants Experienced a 0 to 1 Hour or 1 to 2 Hour Variation in Time of Daylight Exposure Between Consecutive Days

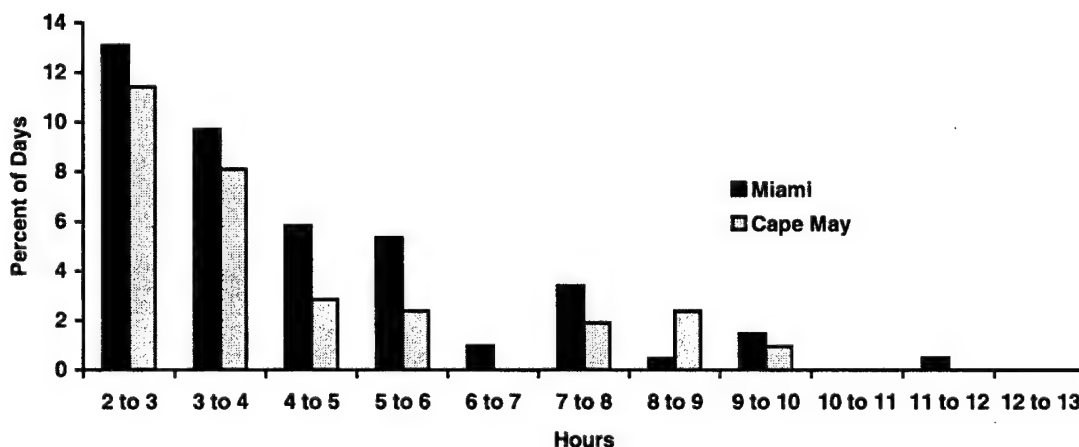


Figure 2. Percent of Days Participants Experienced Variation in Time of Day of Daylight Exposure Between Consecutive Days, with Variations Ranging From 2-13 Hours

¹ One-way ANOVA, ($F [1, 753] = 32.017, p < 0.05$).

Volunteers exhibiting frequent differences above two hours consistently provided unstable inputs to the biological clock's timing. This pattern of inputs can result in daily delays or advances in the clock's internal synchronization. The unstable inputs to the clock can induce shifts in performance and physiological rhythms that are under direct control of the clock's regulatory system. Frequent shifting in these rhythms can result in changes in the time of day in which physiological (e.g., physical stamina) and cognitive (e.g., mental ability to make decisions) resources are available. The unpredictable timing of these resources results in the experience of jet lag like symptoms such as fatigue, degraded alertness, and overall malaise

3.2.2 Daily Differences in Rise Times

It was expected that changes in work schedules would be associated with daily changes in daylight exposure time. Then, the analysis of rise time differences between consecutive days can be a second indicator of the stability or lack of stability of the sleep/wake cycle. Therefore, differences in rise times between consecutive days were analyzed using the same approach employed for daylight exposure changes between consecutive days. Figures 3 and 4 illustrate the percent of days plotted over hours of daily rise time differences between consecutive days. Cape May personnel exhibited a greater frequency of days in the zero to one and one to two hour categories indicating stable reporting times (see Figure 3). Beyond the three hour category (see Figure 4), the trend reversed revealing that personnel at Air Station Miami experienced more frequent changes in reporting times (29.92%) than Cape May personnel (17.48%). The results of a statistical test applied to the differences in rise times between consecutive days supported these observations³.

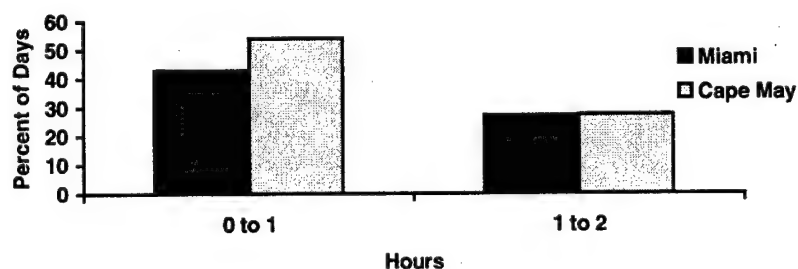


Figure 3. Percent of Total Number of Days Throughout the Study Plotted Over Number of Hours of Change in Rise Time Between Consecutive Days, Ranging from 0-2 Hours

³ One-way ANOVA ($F [1,530] = 1.49, p < 0.05$).

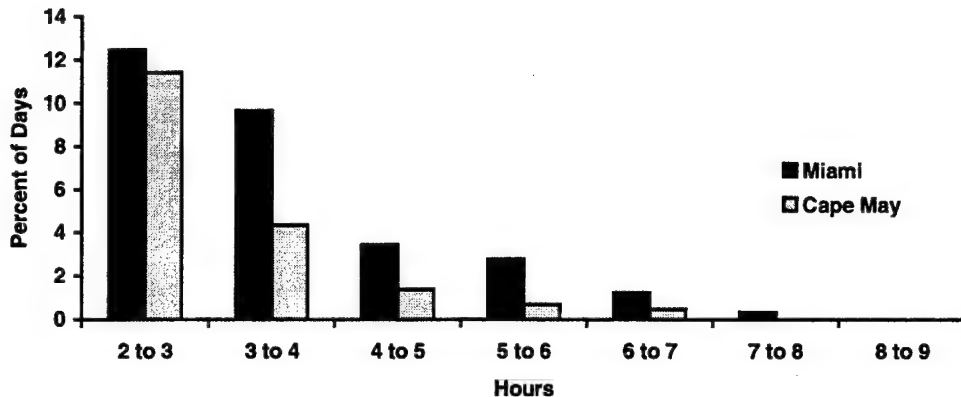


Figure 4. Percent of Total Number of Days Throughout the Study Plotted Over Number of Hours of Change in Rise Time Between Consecutive Days, Ranging from 2-9 Hours

3.2.3 Sleep Duration

Sleep duration differences occurring between consecutive days were calculated for personnel from both air stations. Percent of days were plotted by the number of hours difference between consecutive days. In Figure 5, loss of sleep duration is depicted by negative numbers and increase in sleep duration is denoted by positive numbers. Categories in Figure 5 are labeled by the largest magnitude of the two numbers of the category (e.g., zero to plus one is depicted as +1). Note that personnel at Miami Air Station experienced a greater percentage of days with sleep loss than personnel at Cape May, particularly exceeding two hours of sleep loss. Miami personnel experienced a greater percentage of days under the minus two to minus three, and minus three 3 to minus four hours of sleep loss than Cape May personnel. This observation supports the notion that Miami personnel were exposed to variable duty schedules that resulted in sleep debt of three hours or more. Both groups exhibited a greater percentage of days under categories of zero to plus one (gain) and zero to minus one (loss) hours.

3.2.4 Work Schedule Observations

Work-schedules were documented throughout the period of evaluation. In general, Miami Air Station personnel were exposed to more frequent daily flight missions and deployments to cutters than aircrew at Cape May Air Station. Miami based crew members expressed greater difficulty in coordinating family life and work demands. Frequent deployments to serve on cutters, frequent flight missions, varying work-schedules, and collateral duties were reported as possible causes of significant reductions in personal time to attend to family and social needs.

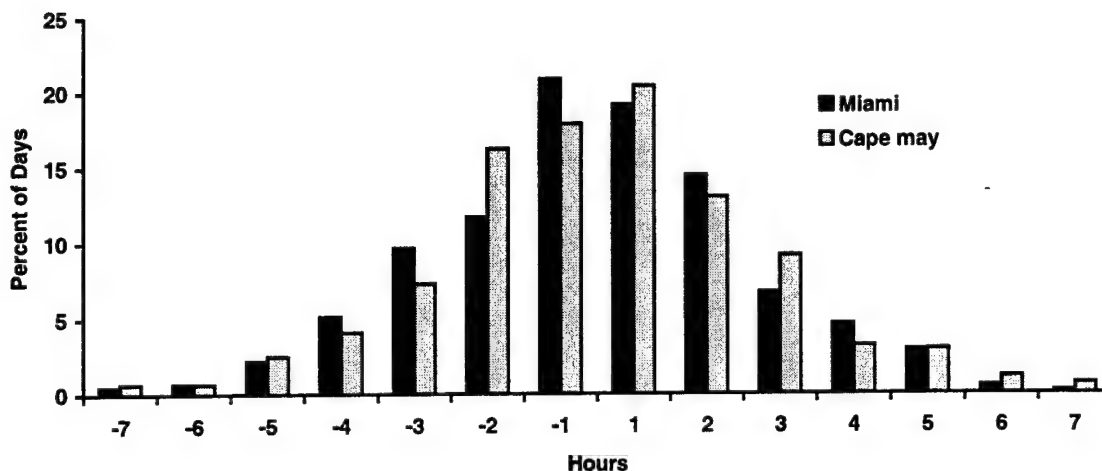


Figure 5. Percent of Days Plotted Over Differences in Sleep Duration Between Consecutive Days. (Negative numbers indicate sleep loss and positive numbers indicate increase in sleep duration. Categories are labeled by the largest magnitude of the two numbers of the category)

The operational tempo at Miami Air Station required a flexible work-schedule system, which even allowed for unscheduled personal requests for time off. This feature provided time off to personnel experiencing personal emergencies. However, the consistently high operational tempo required frequent calls to personnel during scheduled time off. These calls were necessary to backfill for crew members unable to fly due to reaching daily flight time limits, or unable to deploy due to unexpected health problems, or personal reasons.

3.2.5 Sleeping Quarters

At Cape May, crewmembers slept in a building that was completely separated from the air station operations building and hangers. Rooms were well maintained and provided sufficient blocking of daylight. The only possible disruptions of the sleep period were associated with traffic in hallways and proximity to CG enlisted quarters. In Miami, sleeping quarters for officers and enlisted personnel were located within the Air Station in close proximity to hangers and operations buildings. Rooms were equipped with air conditioning units and curtains that provided adequate control of environmental temperature and blocking of daylight. However, rooms were noisy (doors slamming upon shutting), and "piped messages" were likely sources of sleep disruptions.

3.3 Alertness Evaluation

3.3.1 Sleep Latency and Maintenance of Wakefulness Tests

The results of the sleep latency (SLT) and maintenance of wakefulness (MWT) tests were plotted to depict data collected pre-deployment, during deployment, and post-deployment. Figures 6 and

8 depict the frequency of test sessions resulting in normal and abnormal latencies during the sleep and wakefulness tests, respectively. The clinical literature indicates that sleep latencies below six minutes indicate degraded alertness due to disruption of normal sleep (in duration or quality). In addition, in the case of the Mean Wakefulness Test (MWT), short sleep latencies indicate that participants are not able to sustain alertness when exposed to relaxing conditions, thus indicating reduced ability to maintain vigilance performance.

During sleep test sessions (instructions are to sleep), participants exhibited a clear propensity to fall asleep in less than six minutes. Examine Figure 6 and note that plotting the number of test sessions against latencies reveals a large number of test sessions below the six minute mark, particularly for the pre-deployment and post-deployment conditions. Calculating percentages of sleep test sessions falling below six minutes revealed that 58% of pre-deployment, 51% of post-deployment, and 44% of deployed test sessions resulted in outcomes that indicate an abnormal tendency to fall asleep. These observations indicate a trend showing that crewmembers experienced a considerable level of alertness degradation both during deployments at remote sites and on duty at Air Station Miami (pre- and post-deployments). Although, mean latencies in the three conditions were similar (Figure 7), statistical analysis revealed significant differences in sleep latencies between the three conditions, suggesting that participants' alertness degradation was greater at Air Station Miami than on deployment⁴.

Analysis of latencies in the maintenance of wakefulness test (MWT) supported the notion that personnel experienced a greater level of alertness degradation at Air Station Miami than at deployed locations (Puerto Rico and Cuba). At Air Station Miami, MWT latencies were more frequently below six minutes than at the remote locations (Figure 8). Calculating percentages of MWT sessions falling below six minutes in the deployed (17%) and the pre- and post-deployment conditions (47% and 44%, respectively) clearly depicts the emerging trend.

⁴ One way ANOVA, ($F [2,101] = 1.97, p < .05$).

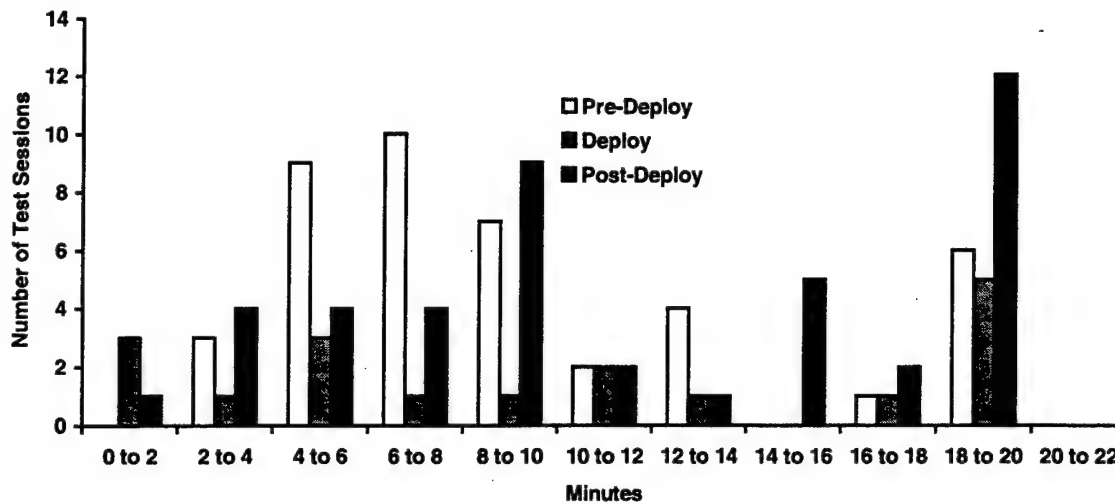


Figure 6. Number of Sleep Test Sessions Plotted Over Latencies to Sleep Onset in Minutes for Pre-deployment, Deployment and Post-deployment Conditions

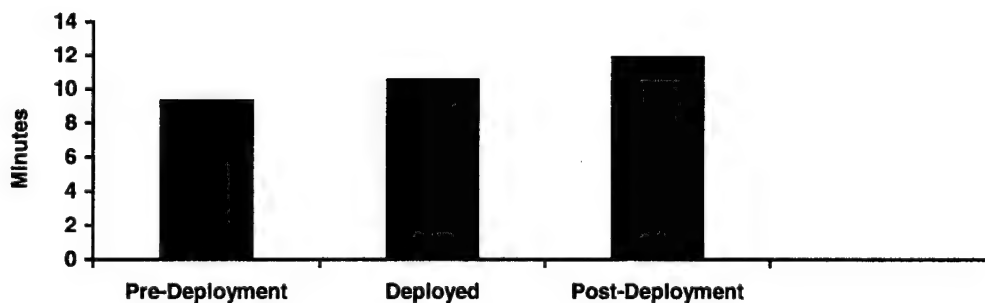


Figure 7. Latency Means of All Sleep Tests Conducted at the Air Station Miami (Pre- and Post-deployment), in Guantanamo, Cuba, and in Barrancken, Puerto Rico (Deployed Condition)

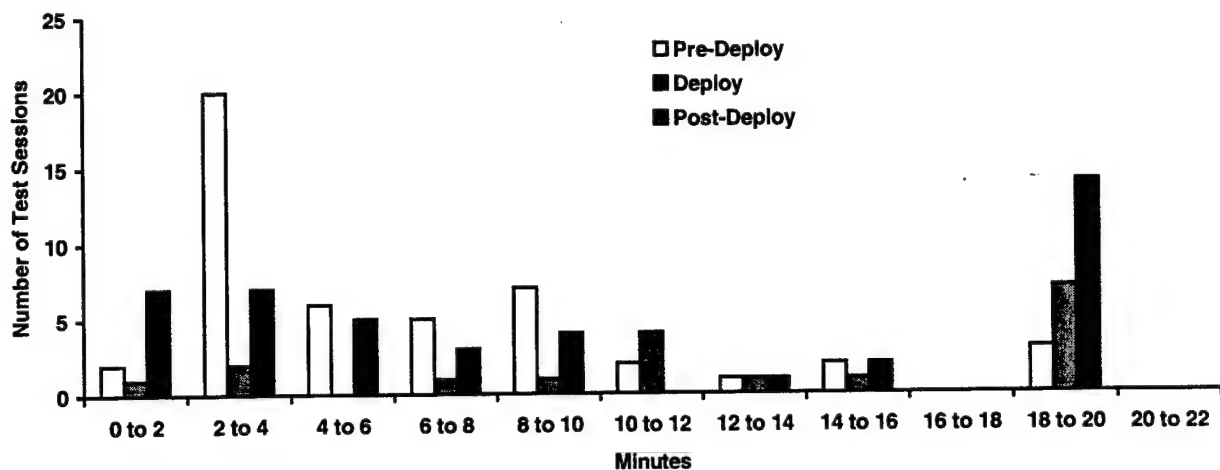


Figure 8. Number of MWT Sessions Plotted Over Latencies to Sleep Onset in Minutes for Pre-deployment, Deployment, and Post-deployment Conditions

A comparison of mean latencies between the three conditions supported the notion that sleep latencies were lower while personnel were on duty at Air Station Miami (Figure 9). A one-way ANOVA, revealed significant differences ($F(2,96) = 4.63, p = .05$) in sleep onset latencies during the MWT between the three conditions. Further analysis corroborated that participants' alertness degradation level was significantly greater at Air Station Miami than at the deployed locations in Barrancken, Puerto Rico and Guantanamo, Cuba (Tukey HSD, $p = .031$).

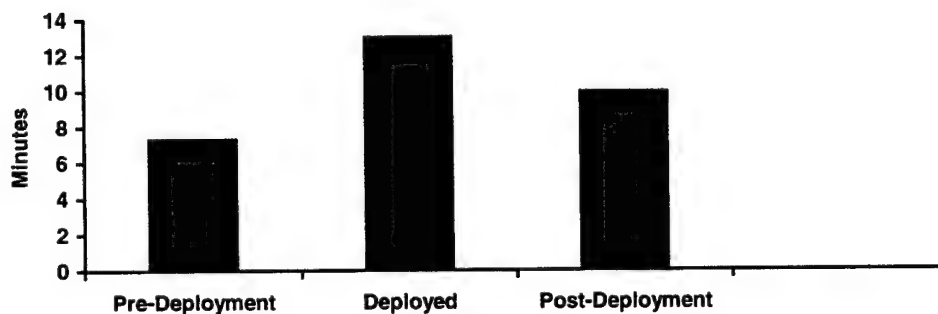


Figure 9. MWT Sleep Onset Latency Means Recorded at the Air Station Miami (Pre- and Post-deployment), in Guantanamo, Cuba, and in Barrancken, Puerto Rico (Deployed Condition)

4 Discussion

Experimental and clinical evidence clearly indicate that rapid shifts in work schedules have a detrimental impact on health and physiological well being of shiftworkers (Kogi, 1985; Scott & Landou, 1990; Smolensky & Reinberg, 1990; Office of Technological Assessment [OTA], 1991). In general, varying reporting times from day to day are often associated with the disruption of the sleep/wake cycle, sleepiness, reduced alertness, deterioration of performance, and physical discomfort associated with gastrointestinal disorders (Comperatore & Krueger, 1990; OTA, 1991). The frequent changes in rise times shown in the Air Station Miami data can result in the disruption of the timing of the biological clock and in sleep loss. These variations may have induced changes in alertness similar to the sleepiness reported by the lay person during the transition to daylight savings time. Usually this change is only a one hour advance in rise time and daylight exposure time, yet it is well documented that the U.S. population at large experiences sleepiness during the first week of this change.

In the evaluations conducted at Air Stations Cape May and Miami, alertness and endurance data indicate that Miami aircrews were more apt to experience drastic changes in their sleep/wake cycles and daylight exposure times. In the case of Miami personnel, changes in rise times and daylight exposure times varied often by more than three hours, and occurred several times within a month or sometimes within a week. These changes in daylight exposure times were likely to induce lack of stability of the sleep/wake cycle and of the internal timing of the biological clock. The results of sleep and wakefulness tests supported this notion and provided evidence of reduced alertness. Latencies to sleep onset in both sleep and wakefulness tests indicated a disturbing pattern of alertness degradation similar to the deterioration experienced by patients suffering from sleep disorders.

The value of this research effort rests not only on the ability to detect evidence of alertness degradation, but also on the ability to formulate practical and efficacious preventive measures. Thus, we now turn to the description of the use of a specific method to:

- 1) Consider the impact of these finding on the operational efficiency of Air Station Miami, and to
- 2) Design a plan to prevent the subsequent degradation of performance, alertness, and safety during normal operations.

4.1 The Crew Endurance Management System

The System Approach to Crew Rest (Comperatore, 1996) was adapted for the specific requirements of U.S. Coast Guard aviation missions. Following, we provide a more detailed description of the Coast Guard version of the Endurance Management System or CGEMS. This system coordinates mission specific objectives, workload, human resources, work schedules, equipment constraints, administrative duties, and family and social activities to prevent sleep loss, high stress levels, and performance degradation during aviation missions (Comperatore, 1996; Comperatore and Allan, 1997). The CGEMS consists of mission specific plans designed to maximize alertness during flight operations by optimizing sleep efficiency during rest periods

and reducing emotional stress. A model, consisting of four levels, coordinates rest periods, days off, and personal time with unit activities conducted to accomplish mission objectives (Figure 10).

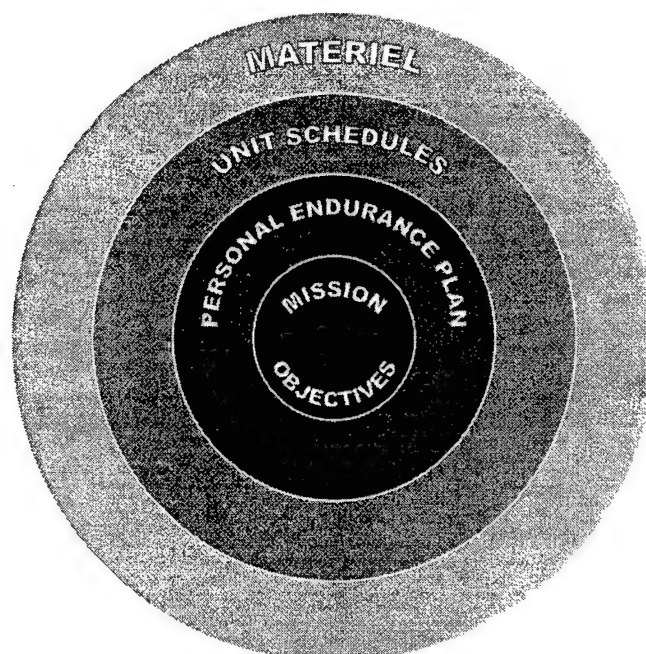


Figure 10. CGEMS Model Depicting the Four Levels and the Relative Flexibility of Each Level. (Mission objectives (Level I) is the least flexible level, indicated here by a central position. Levels increase in flexibility away from the center.)

4.1.1 The Center of the Model

Mission demands are at the center of the model and they are the reference for all other coordination. This first level element of the system consists of the type of mission (e.g., SAR or Law Enforcement), the number and types of aircraft (e.g., AH-65 helicopters or Falcon jets), time of day of mission (e.g., nighttime), and weather conditions. The effectiveness of the CGEMS relies on its emphasis of adjusting the plan to the mission's objectives and on the ability to maximize rest and alertness by implementing a practical and well-coordinated plan.

4.1.2 The Second Level: Personal Endurance

In the second level, the CGEMS prescribes crewmember activities to maintain high levels of alertness during duty hours, maximize sleep efficiency, regulate the biological clock, and maximize the balance between family life and work demands. Table 1 depicts some of these prescribed activities. The success of these individual efforts depends on their coordination with the first, third and fourth levels of the model. Refer to Appendix C for suggested personal endurance plans.

Table 1. Sample of CGEMS Prescribed Level II Activities

Level II Activities	Functional Significance
Design sleep management schedules to meet the demands of mission flights	Prevent fatigue induced by short duration sleep periods and optimize sleep by prescribing best times of the day to sleep
Implement recommendations to optimize the sleep environment	Control of noise and light intrusions prevent fatigue induced by unnecessary fragmentation of the sleep period
Implement daylight exposure schedules	Prevent fatigue and performance degradation induced by the disruption of the body's internal timing system (Shift-Lag)
Inform family members in advance of deployment schedule and plan at least one family activity prior to departure	Reduce alienation of family members and use actions to demonstrate affection
Schedule meals and control composition of meals to minimize digestive disruptions	Minimize sleep disruption induced by disrupted digestive function

4.1.3 The Third Level: Unit Schedules

This level consists of unit activities that directly impact the mission and crew readiness. These activities need to be planned and scheduled so that they simultaneously accomplish the mission, and also, promote crew alertness. Such activities include briefings, planning sessions, meal schedules, aircrew scheduling, training schedules, deployment schedule, and schedules of instruction periods on crew endurance management for all unit personnel.

4.1.4 The Fourth Level: Materiel

The elements of this level constitute activities related to the maintenance of mission essential equipment (e.g., helicopters, fixed wing aircraft, swimmers' equipment, rescue equipment, etc.). Maintenance schedules and schedules of aircraft availability for planned and emergency mission flights are critical elements in this level of organization.

4.2 Implementation of the CGEMS

The process of implementing the CGEMS to develop a crew endurance plan requires an initial evaluation of the impact of the unit's current operational policies on crew rest. This evaluation must be conducted during at least a 15-30-day period to properly document duty hours, workload, and crew rest associated with low and high tempo operations. Depending on the geographical location (e.g., Alaska vs Florida), operational tempo and workload may be directly affected by seasonal changes; thus, some evaluations must be conducted during both winter and summer seasons. This evaluation provides information on the elements that require coordination across the four levels of the system.

In addition to this analysis, the successful implementation of the CGEMS requires the activation of an aggressive education program designed to instruct wardroom officers, chiefs, and unit personnel on their contribution to the coordination and execution of the various elements. In the following sections we discuss the results of the initial evaluation or Phase I and then use the CGEMS to develop the endurance plan.

5 Conclusions and Recommendations Based on the Results of the Initial Evaluation

5.1 Recommendation: Make Work Schedules Predictable

The observations of chronically high operational tempo and of unpredictable work-schedules supported the notion that the unstable inputs to the biological clock induced alertness degradation. Since operational tempo resides in the first layer of the crew endurance model and it is the center of all other coordination, the model prescribes no changes at this level of organization. However, work schedules, an element of the third layer of the CGEMS model, is a target for potential improvements. One characteristic of the work schedule was its flexibility. This was a characteristic that allowed "backfilling" (terminology used at Air Station Miami) by calling back to duty personnel who were otherwise off-duty. Two events were found to trigger the need to call off-duty personnel, namely, increased operational tempo and unscheduled requests for time off. Although backfilling a crew position was inevitable when operational tempo was the sole cause of this action, calling off-duty personnel to duty can result in frequent disruptions of personal and family time. Thus, the combined impact of operational tempo and unscheduled requests for personal time off can result in long term aversive consequences to the dynamics of personal and family life. One may consider that when unscheduled requests for time off cause backfilling actions, their adverse impact on the unit may not justify the temporary benefit to the individual. Thus, backfilling could be minimized if its causes are strictly limited to

operational tempo and unavoidable health impairments. This recommendation restricts the current flexibility of work schedules, but its benefits may extend from a more reliable and predictable work schedule to a significant increase in family and personal quality time. From a human endurance point of view, the quality of time off may be as important as the quality and duration of sleep.

5.2 Recommendation: Improve Sleeping Environments

In addition to restricting backfilling actions, some improvements to the sleep environment may also contribute to ensuring that personnel at Miami Air Station experience uninterrupted sleep during 24-hour duty days. Environmental improvements, also a third level element of the crew endurance model, are easy targets for improvements. During the evaluation of environmental conditions, doors in the hallways of sleeping quarters produced loud sounds upon closing. Suggestions to equip the doorframes with thick foam weather stripping that may soften the slamming sound were met with favorable responses. In addition, we recommend minimizing the use of "piped calls" to avoid sleep disruption in enlisted and officer quarters. Selectively disabling speakers and installing direct telephone lines with access to flight operations may be a practical and feasible approach.

5.3 Recommendation: Educate CG Personnel on Endurance Management

The CGEMS prescribes the aggressive use of an educational program to disseminate sleep hygiene and endurance practices information throughout all rank and occupational levels. This action is particularly relevant to occupational environments with high operational tempo. In these situations, as is the case at Air Station Miami, personal choices may be extremely important in the maintenance of endurance. For instance, only individuals make choices to nap when the opportunity arises, or to choose to delay completing paperwork associated with collateral duties in favor of a needed nap prior to a night mission. Safety down days or scheduled workshops can provide the environment to disseminate information on personal endurance plans (CGEMS Level I activities) and on the design of crew endurance plans using the CGEMS and the Army's CEMS. Educational materials are available at the USCG Research and Development Center in Groton, CT.

5.4 Recommendation: Implement the Endurance Plan at Air Station Miami

Air Station Miami recently sponsored a crew endurance seminar conducted by USCG R&D and HQ staff. This is one of the many actions that the Air Station's command staff has supported after this initial evaluation. Other significant changes to date constitute the formation of a quality action team (QAT) to determine possible changes in work-schedule practices, improvements to the sleep environment, and the organization of an educational program. Once the QAT designs and implements changes to improve performance and prevent stress and sleepiness in the operational environment, a second evaluation will determine the efficacy of the endurance plan. Coast Guard Research and Development resources have been assigned to assist Air Station Miami to evaluate the efficacy of the endurance plan.

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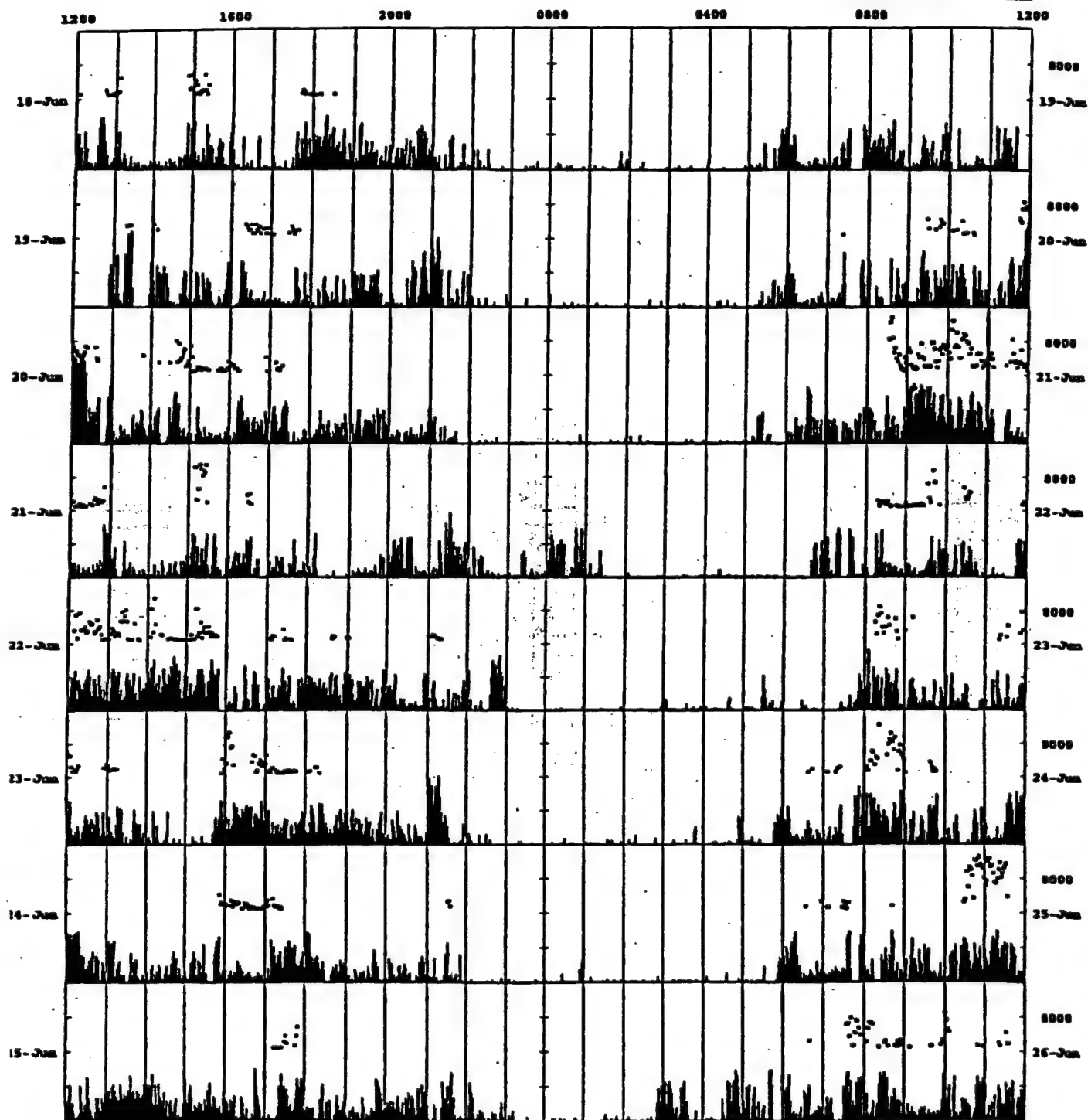
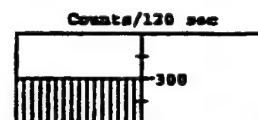
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Appendix A
Air Station Cape May

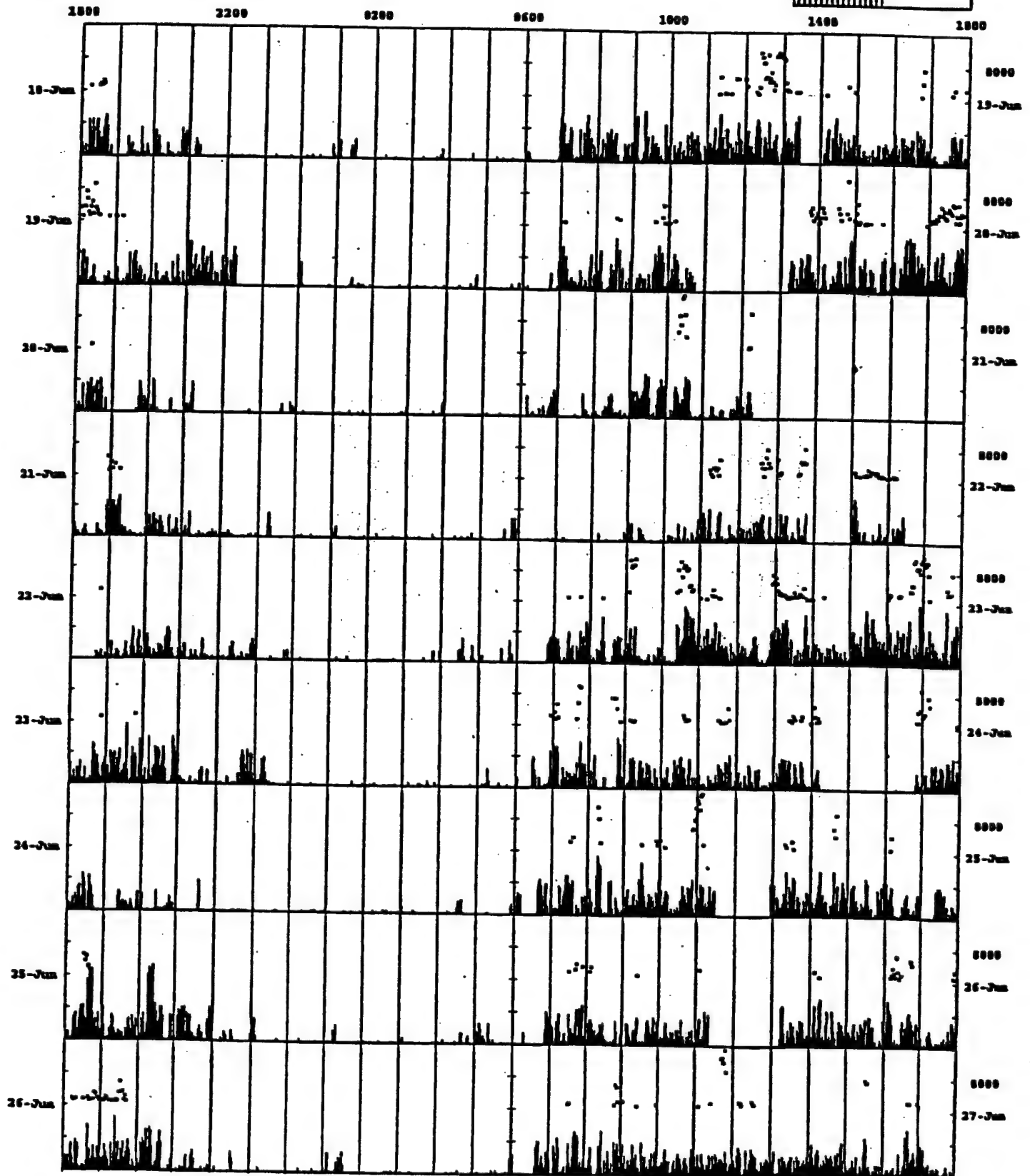
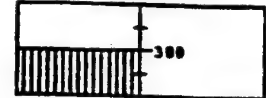
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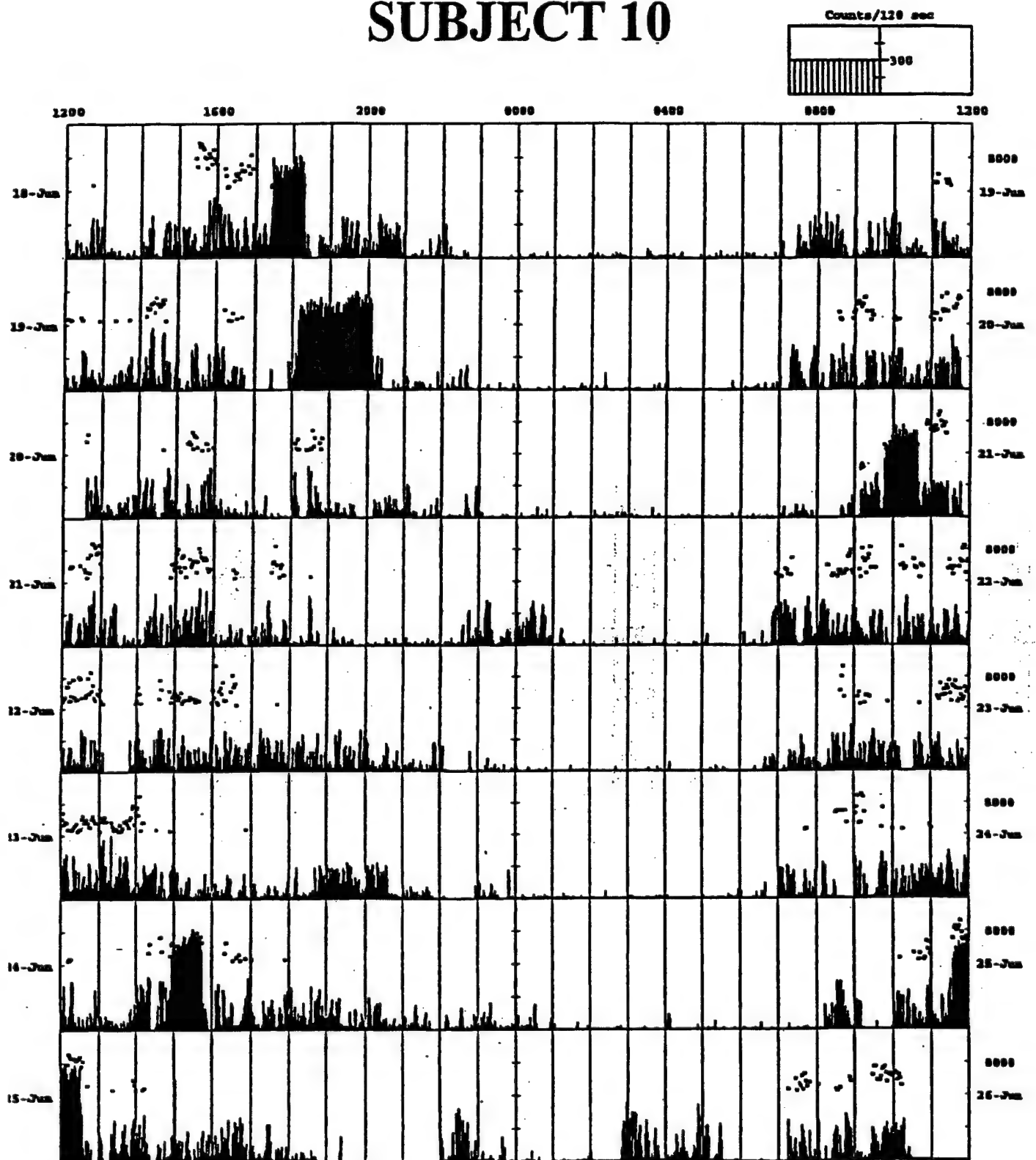


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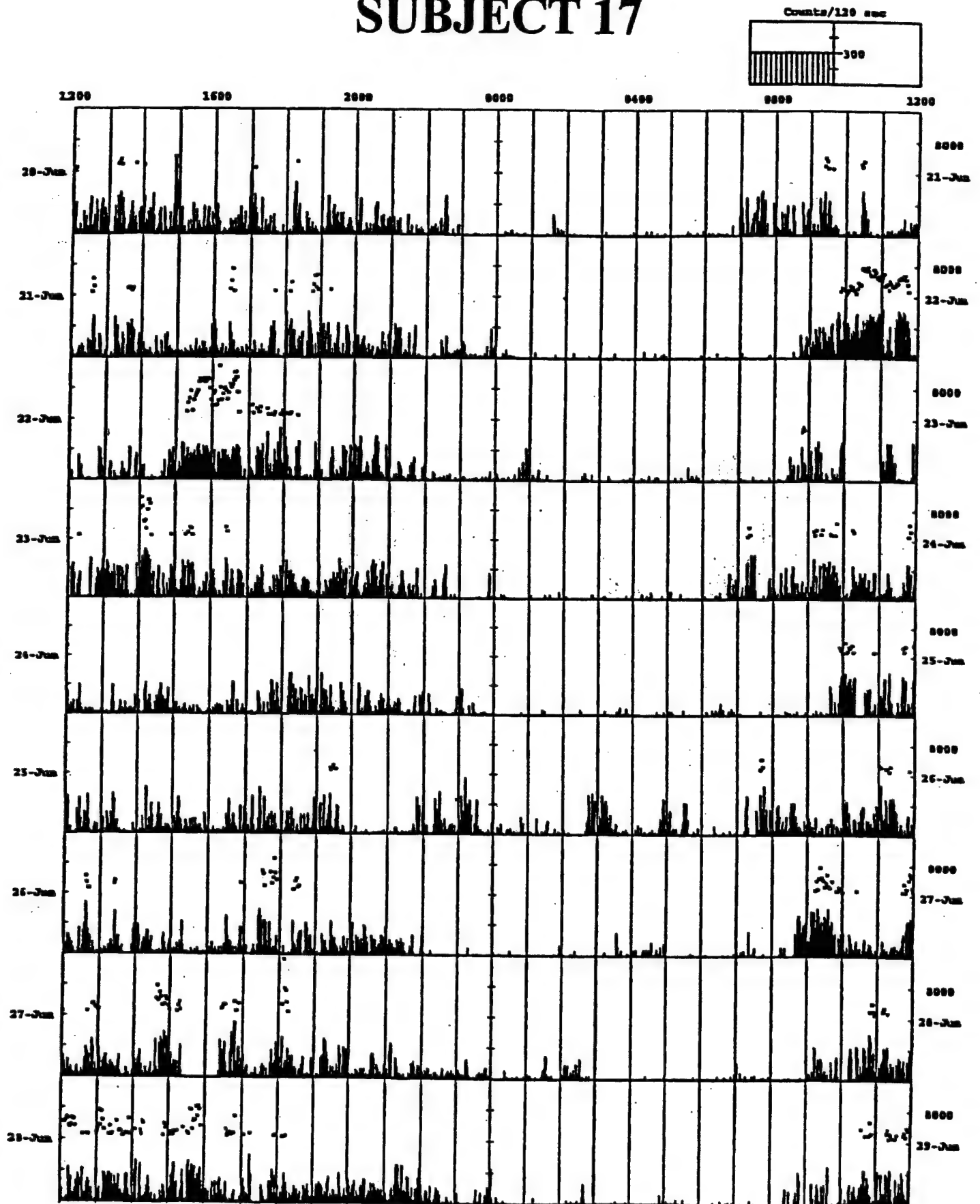
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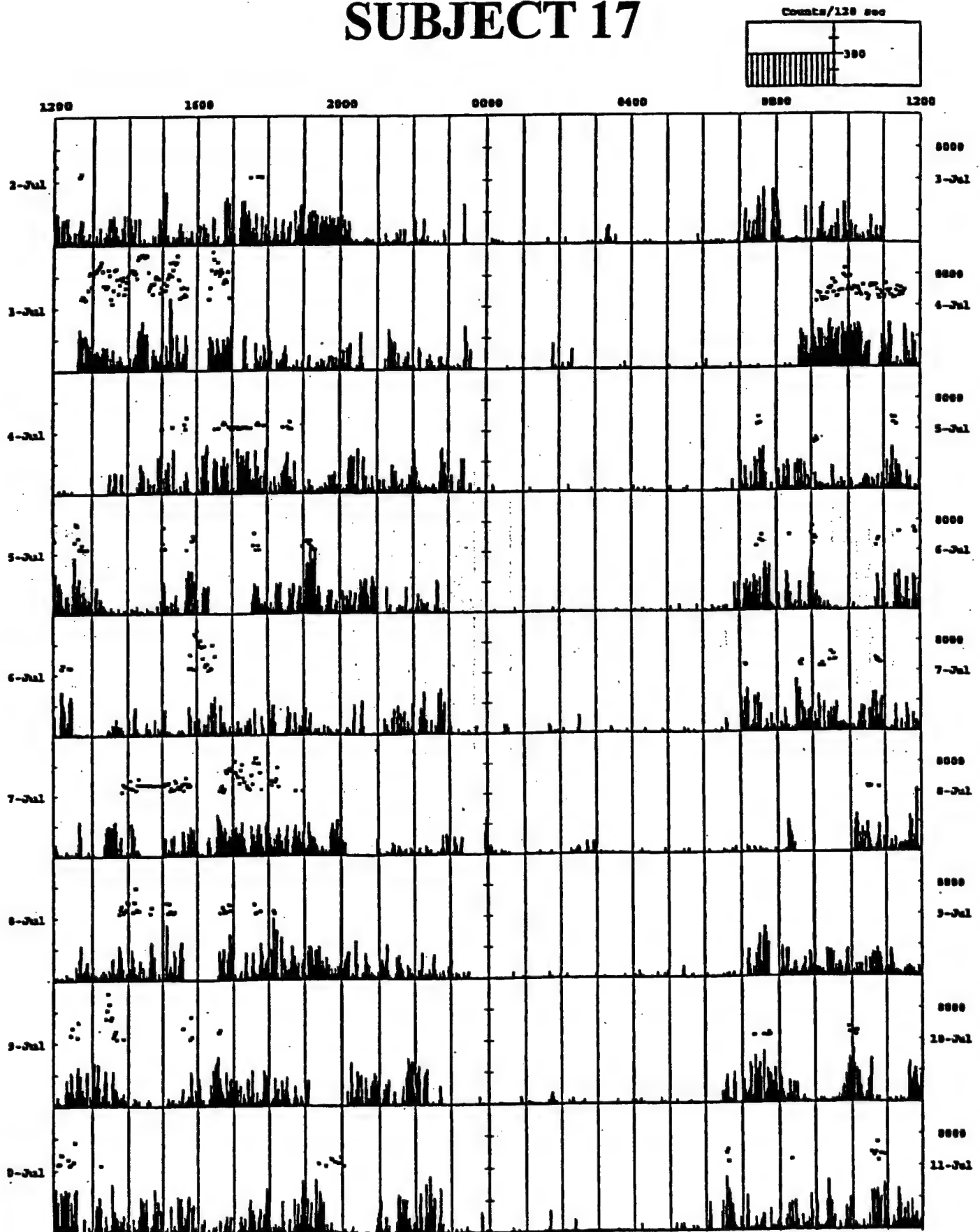
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SUBJECT 17



SUBJECT 17



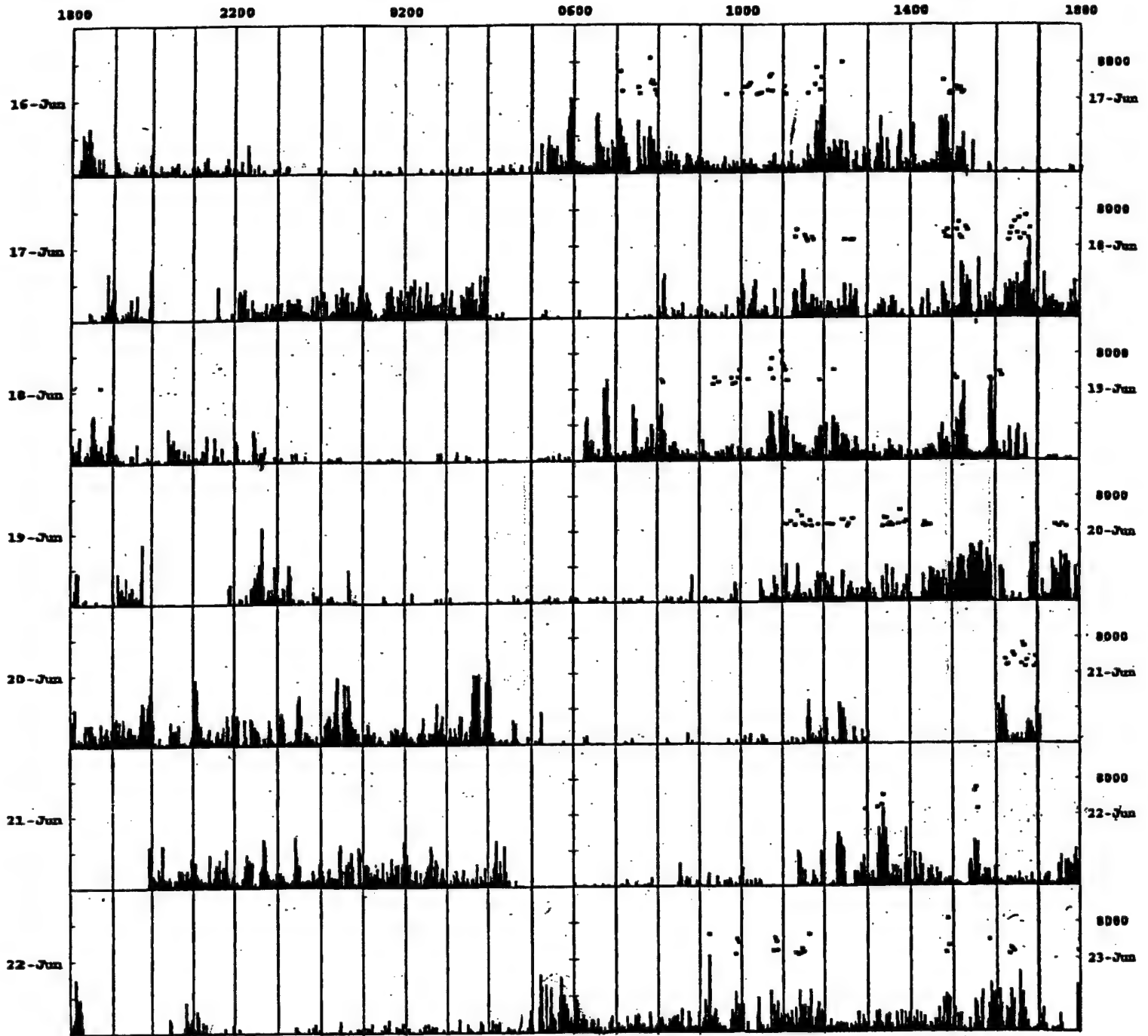
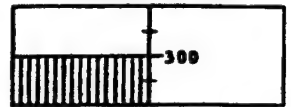
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Appendix B
Air Station Miami

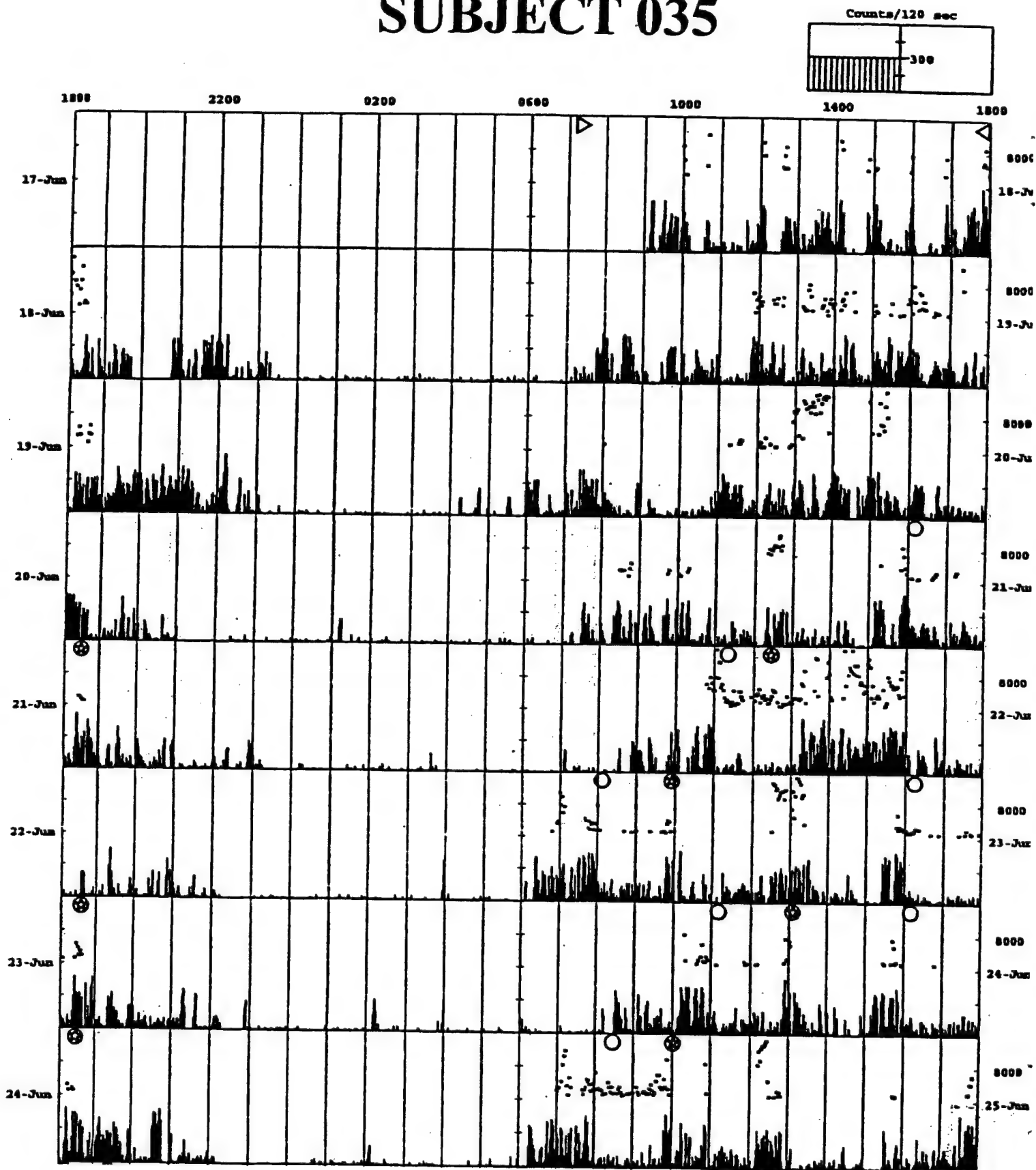
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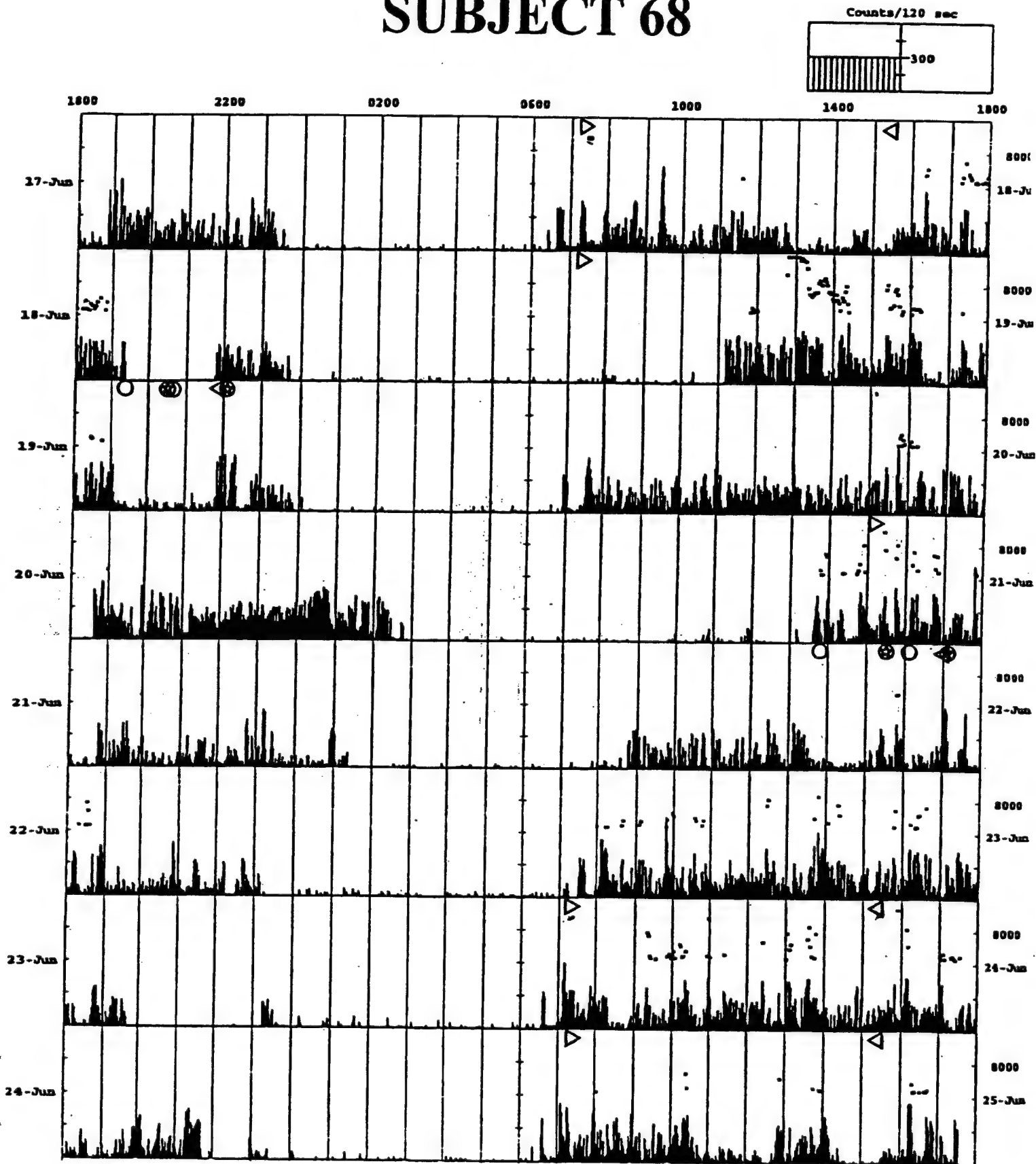
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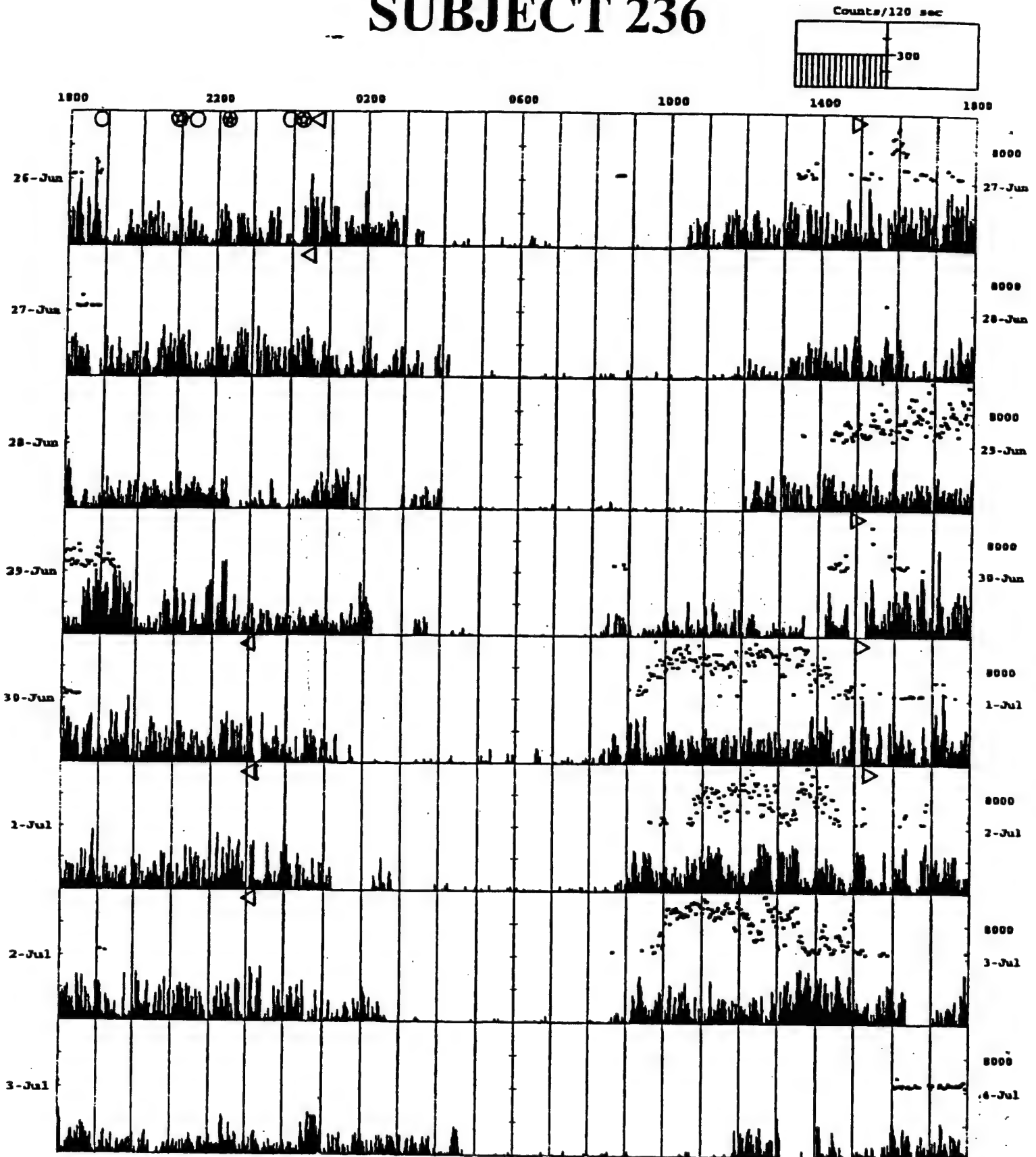
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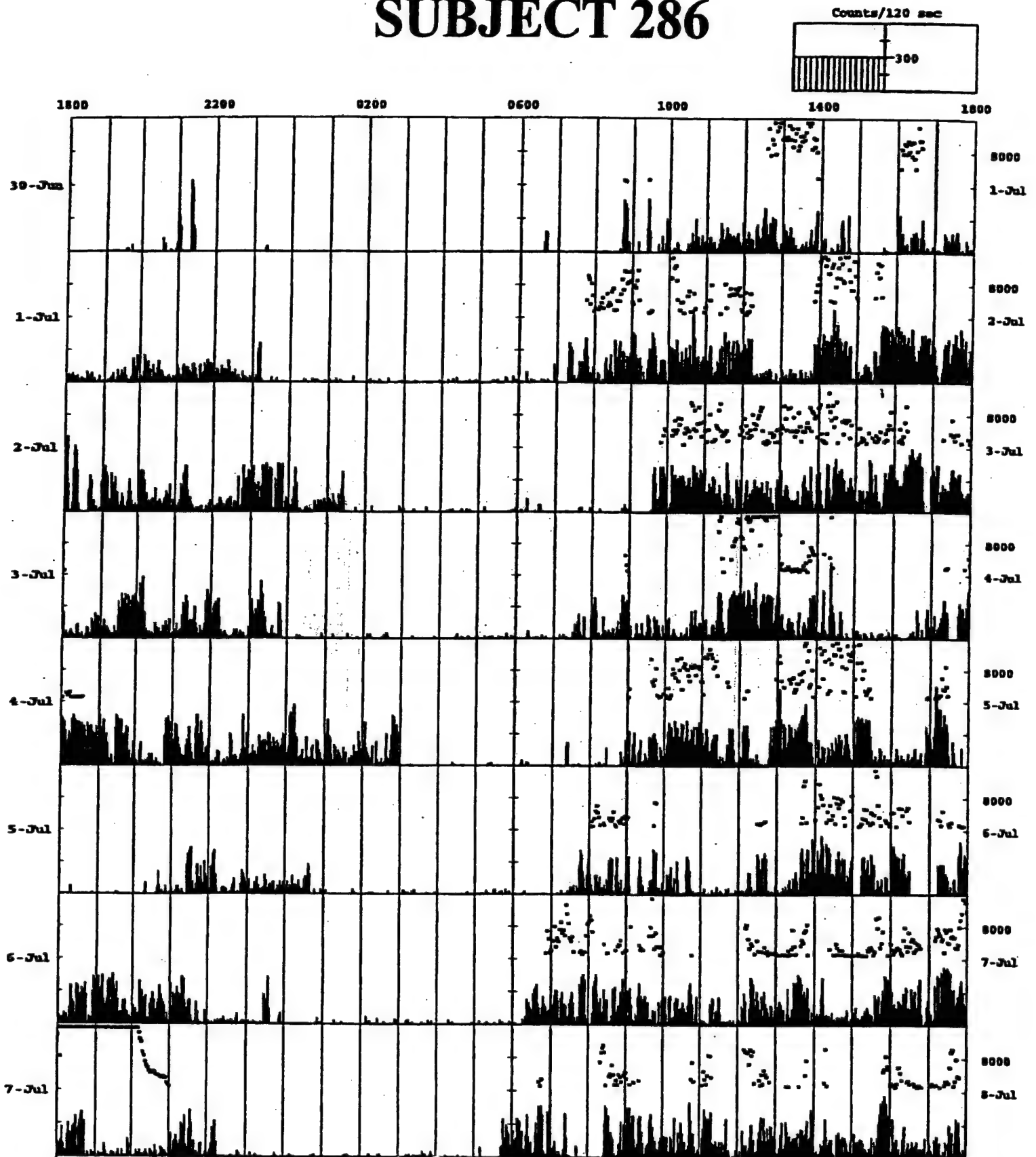
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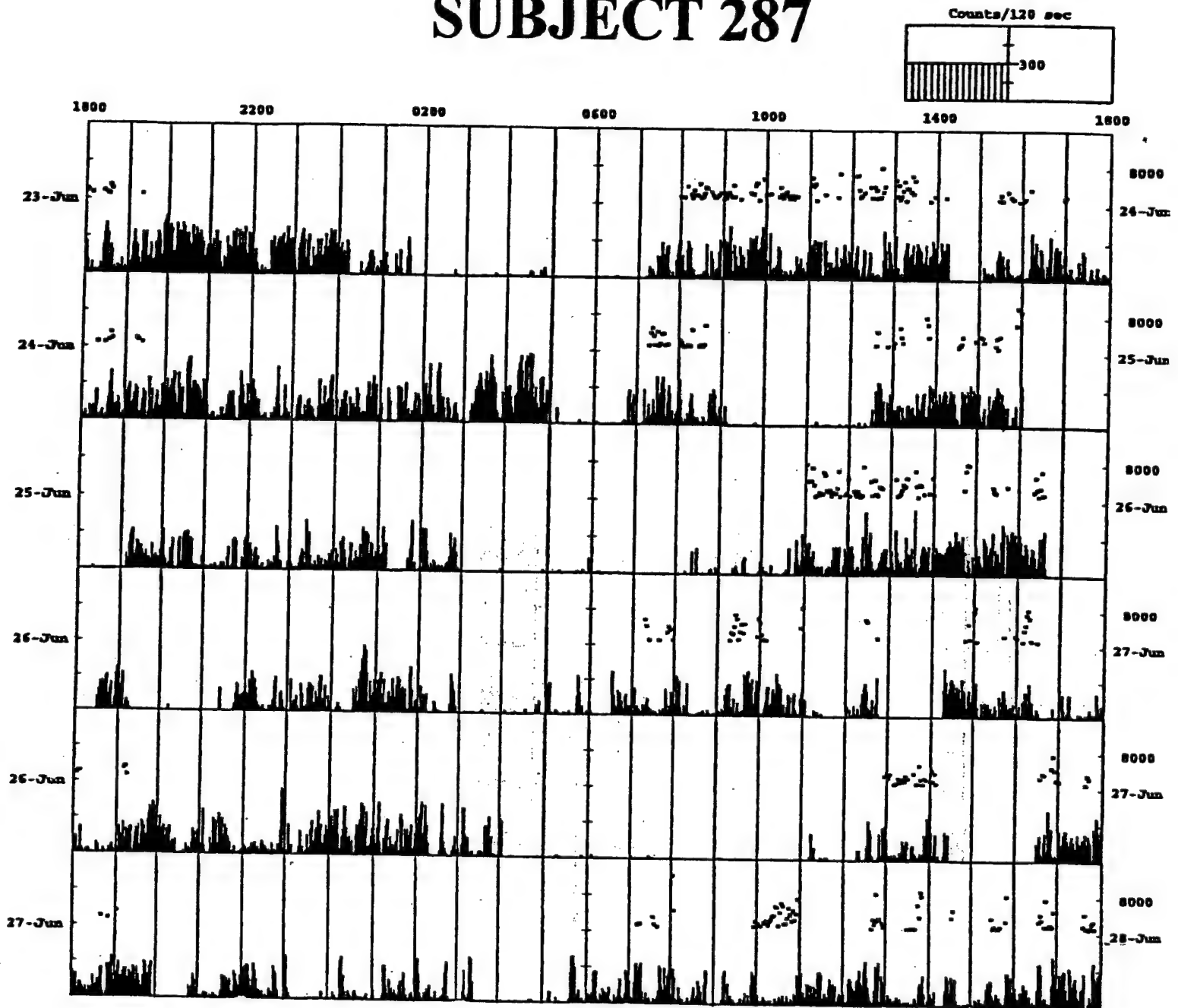
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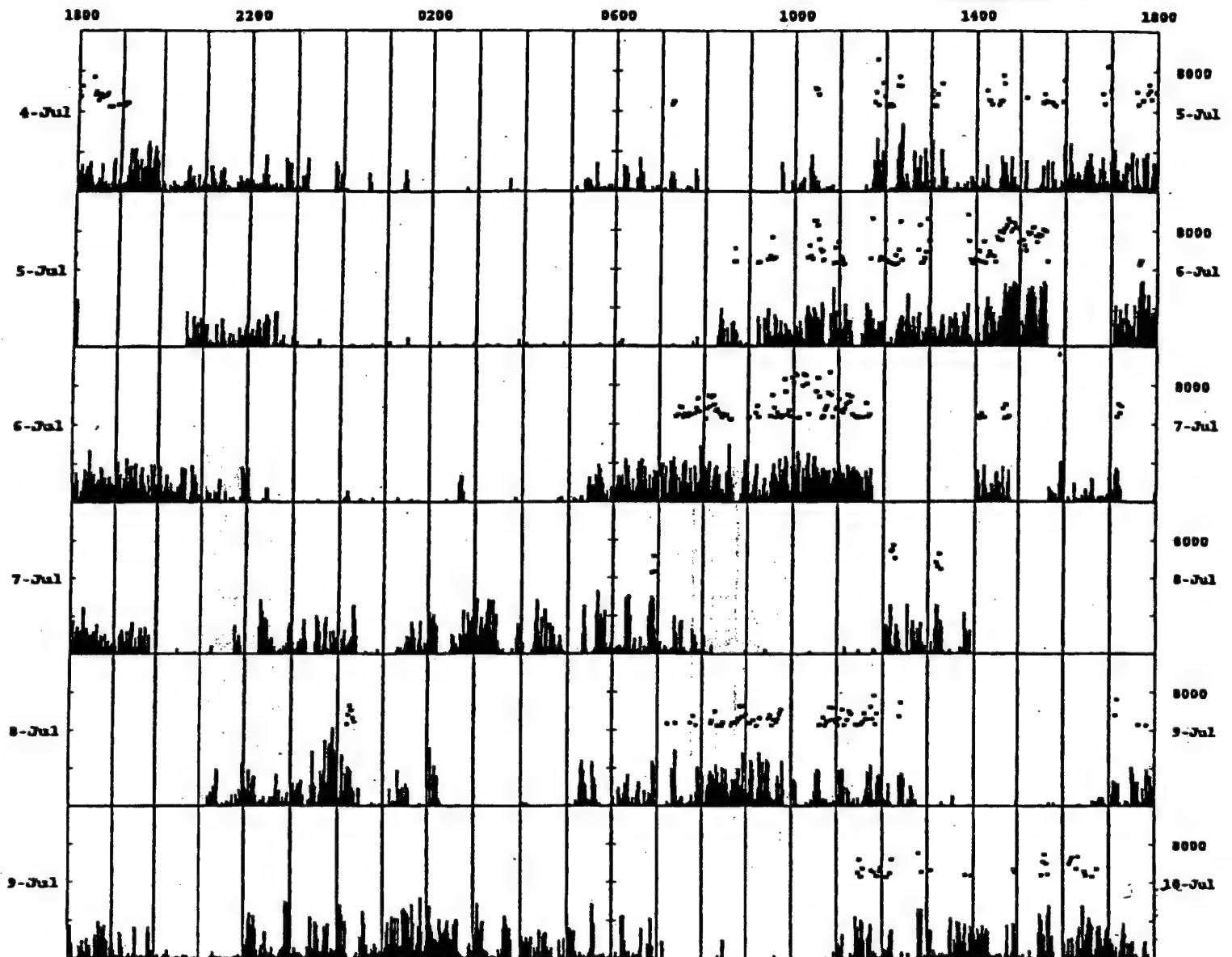
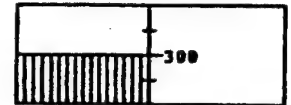


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Appendix C
Mission Specific Personal Endurance Plans

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Early Morning Day Shifts Alternating with Afternoon Duty Times

- a. Maintain an early morning circadian orientation by consistently waking up and seeing daylight in the early morning hours (0500-0600) as well as retiring in the early evening hours (2000-2200).
- b. Prevent sleep disruption by reducing alcohol and caffeine consumption during the evening hours.
- c. After working all night and at the end of a 24-hour duty day, nap prior to leaving the air station (preferably two hours), then that night, retire at your usual bedtime.
- d. Give yourself at least 15 minutes after awakening from a nap before operating any vehicle or conducting activities which may require alertness to prevent hazards and to avoid the adverse effects of sleep inertia on performance.

During 24 hour duty Days

- a. Use napping to compensate for sleep loss. Two-hour naps restore alertness for longer periods than shorter naps, but napping is always better than not napping. Be aware of sleep inertia immediately after awakening from a nap.
- b. Retire at your usual bedtime if possible. This period of sleep should last as long as possible up to seven-eight hours.
- c. If this sleep period is short (less than six hours) attempt to reduce sustained wakefulness prior to flights below eight hours. That is, if possible, nap (one-two hours) every eight hours of sustained wakefulness.
- d. Remain on a day oriented daylight management plan.

Long Term Nighttime Duty Hours

- a. Maintain consistent bedtimes and rise times, as well as daylight exposure, to prevent shift lag.
- b. After the night shift, retire as soon as possible.
- c. Avoid seeing daylight before bedtime for more than one hour after sunrise.
- d. Sleep as long as you can after the night shift.
- e. Use napping to compensate for sleep debt if your sleep is shortened below six hours.

- f. Rotation into nighttime duty hours requires at least three days to adapt. Expect to experience fatigue throughout the night until full adaptation is achieved. The first three days pose high risk due to circadian rhythm desynchronization and concurrent performance degradation.
- g. Avoid intermittent rotations to daytime active schedules during weekends or days off.
- h. Schedulers should maintain crewmembers on nighttime duty hours for at least two weeks to prevent shift lag.
- i. After night duty maintain alertness during the drive home by listening to a radio show that keeps you interested, maintaining the ambient temperature as cold as possible, or keeping the driver's window opened. If possible, carpool and maintain conversation with the driver. Keep in mind that sleepiness and fatigue are unavoidable at the end of a night shift. However, if possible, avoid drinking caffeine within four hours prior to bedtime. Simply avoid alcohol within three to four hours prior to sleep. Alcohol disrupts the quality and restorative efficiency of sleep.

Short Term Nighttime Duty Hours (Less than 3 days)

Avoid the use of this work schedule when possible

- a. Performance degradation and excessive levels of fatigue are unavoidable during the second night, particularly in cases in which flight missions are launched during two consecutive nights.***
- b. Use napping to compensate for reduced sleep duration (less than six hours).
- c. If possible, nap prior to the mission to enhance alertness during the mission.
- d. If possible, duty hours should be reduced below eight hours, particularly on the second duty day.
- e. Mission permitting, do not fly during the early morning hours (0400 and later).
- f. Attempt to reduce sustained wakefulness prior to flights below eight hours. That is, if possible, nap (one-two hours) every eight hours of sustained wakefulness.
- g. During the drive home, maintain alertness by listening to a radio show that keeps you interested, maintaining ambient temperature as cold as possible, or keeping the driver's window opened. If possible, carpool and maintain conversation with the driver. Keep in mind that sleepiness and fatigue are unavoidable at the end of a night shift. However, if possible, avoid drinking caffeine within two-three hours prior to bedtime to improve sleep quality and duration. Always avoid alcohol three to four hours prior to sleep. Alcohol disrupts the quality and restorative efficiency of sleep.